Market Research on Commodity Wood Products from 8 Non-Native, Hawaiian Grown Timber Species

October 1999

Prepared for

Hawaii Forest Industry Association

Funded by

the USDA Forest Service

through the

Hawaii Forestry & Communities Initiative

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JAAKKO PÖYRY CONSULTING (ASIA-PACIFIC) PTY LTD

Rob de Fégely
EXECUTIVE VICE PRESIDENT

29 October 1999

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Glossary

%	Percent
°C	degrees Celsius
a	Year
ADt	air dry tonne
AR	after reconditioning
asl	above sea level
BDt	bone dry tonne
bf	board foot (1 bf = 1/12 cubic foot)
BR	before reconditioning
CIF	cost, insurance and freight
cm	Centimetre
CSIRO	Commonwealth Scientific & Industrial Research Organisation (of Australia)
DBH	diameter at breast height
DHHL	Department of Hawaiian Home Lands
DLNR	Department of Land & Natural Resources
DOFAW	Division of Forestry and Wildlife
emc	Equilibrium moisture content
FOB	free on board
fsp	fibre saturation point
g	Gram
GDP	gross domestic product
GNP	gross national product
GPa	Gigapascal
h	Hour
ha	hectare (10,000 m^2 = 2.471 acres)
IRR	internal rate of return
kg	Kilogram
km	Kilometre
kWh	kilowatt hour

LVL	laminated veneer lumber
m	Metre
m^3	cubic metre (1 m^3 = 424 board feet)
m^3/ha.a	cubic metres per hectare per annum
m^3sob	solid cubic metre measured over bark
m^3sub	solid cubic metre measured under bark
MAI	mean annual increment
masl	metres above sea level
Mbf	1,000 board feet (1000 board feet = 2.358m^3)
MC or mc	moisture content
mcs	maximum crushing strength
MDF	medium density fibreboard
ml	Millilitre
MMbf	1,000,000 board feet
moe	modulus of elasticity
mor	modules of rupture
MPa	Megapascal
MTH	mixed tropical hardwoods
ob	over bark
ODt	oven dry tonne
OSB	Oriented strand board
ROI	return on investment
QFS	Queensland Forest Service
t	tonne (1 metric ton = 1.1023 US tons)
tpa	tonnes per year
ub	under bark
USD	US dollars
WPC	wood paying capacity = the highest price a wood industry can afford to pay for the raw material and still break even

Preface

This study and report presents data and analyses relevant to assessing technically feasible and market competitive development opportunities for the wood and wood products industry in Hawaii. It also includes a literature review on the following Hawaiian grown species:

Flindersia brayleyana (Queensland maple)
Grevillea robusta (silver oak, southern silky oak)
Toona ciliata (toon, Australian red cedar)
Fraxinus uhdei (tropical ash)
Eucalyptus robusta (swamp mahogany)
Eucalyptus saligna (saligna, Sydney blue gum)
Eucalyptus grandis (rose gum, flooded gum)
Cryptomeria japonica (sugi)

In relation to these species, the following aspects have been researched:

- the cost of bringing a unit volume to market
- practical value adding processing alternatives
- three possible market products for each species
- demand for each market product in Hawaii
- potential export demand
- prices of competing products
- quantity estimates of volumes for each species on forested lands.

This report, prepared by Jaakko Pöyry Consulting with the assistance of Steve Smith of Forestry Management Consultants-Hawaii, will be used by the Hawaii Forest Industry Association (HFIA) as an integral part of the overall goal to increase demand for Hawaiian made commodity wood products, and consequently create more forestry related jobs in Hawaii.

Technical profiles of each of the studied timbers are designed to be used by the HFIA as a guide to the features of each timber species and the potential applications of each species for industry in Hawaii. A description of all terms used in these profiles is included.

Executive Summary

Introduction

This report reviews eight exotic species grown in plantations in Hawaii and includes their physical and mechanical properties, the processing characteristics of their wood; and the potential quantities available as sawlogs and pulpwood from the Hamakua and Waiakea State owned plantations.

The report presents information and analyses relevant to assessing the technically feasible and market competitive development opportunities for wood and wood products industries in Hawaii using the eight species.

Species Descriptions

Individual species descriptions are provided in the report. Table 1 summarises these descriptions for the more important wood characteristics. For definitions of the terms used, the reader is referred to Section 1 of the main report.

Resource Availability

The only reliable resource information for the eight species came from inventory data of the Division of Forestry and Wildlife for the Waiakea and Hamakua State owned plantations. The anticipated annual quantities of sawlogs and pulpwood (including lumber sawmill residues) and lumber output are shown in Tables 2 and 3, based on the assumption that the plantations would be harvested over 15 years. In addition to the eight named species which are the subject of the report, there are other unidentified species in the Hamakua plantation which are of sawlog size and which could increase the combined Waiakea/Hamakua resource by about 18%.

Table 1: Summary of the Species Descriptions

Common name	Botanical name	Density	Seasoning characteristics	Radial and tangential shrinkage	AR[1]	Natural durability	Strength group	Characteristic defects	Termite resistance	Lyctus susceptibility
Rose gum	*E. grandis* [2]	Medium	Easy to moderately difficult to season	Radial Tangential	3.4% 5.2%	Moderate	S4 SD4	Very prone to attack by marine borers	Not resistant Heartwood resistant to treatment with preservative	Resistant
Swamp mahogany	*E. robusta*	High	Rather difficult to season	Radial Tangential	7% 9%	Moderately durable to durable	S4 SD4 to SD5	Dimensionally unstable Brittleheart	Moderately resistant Heartwood untreatable	Susceptible
Saligna	*E. saligna*	High	Seasons easily but must be reconditioned after collapse	Radial Tangential	3.7% 5.4%	Moderate	S3 SD3	Dimensionally unstable Prone to attack by marine borers	Not resistant Heartwood resistant to treatment with preservative	Susceptible
Queensland maple	*Flindersia brayleyana*	Medium	Moderately difficult to season because of interlocked grain	Radial Tangential	3% 6.5%	Moderately durable to durable	S6 SD6		Attacked by dry wood termites Heartwood resistant to treatment	Resistant
Tropical ash	*Fraxinus uhdei*	Medium	Seasons easily	Radial Tangential	2.1 to 4% 4.1 to 7%	Perishable	S5	Susceptible to blue stain	Not resistant Heartwood moderately resistant to treatment	Susceptible
Silver oak	*Grevillea robusta*	Medium	Seasons slowly	Radial Tangential	2% 5%	Moderately durable to perishable	S6 SD5	Liable to marine borer and pinhole borer attack	Not resistant Heartwood moderately resistant to treatment	Susceptible
Toon	*Toona ciliata*	Medium to low	Seasons easily	Radial Tangential	1.5% 3%	Hawaiian wood is perishable	S7		Probably not resistant in Hawaii The wood is resistant to treatment	Susceptible
Sugi	*Cryptomeria japonica*	Low	Care needed to avoid checks and splits	Radial Tangential	2% 4%	Moderately durable to durable	S7 SD8	Frequent knots	Not resistant Wood can be treated	Not attacked

[1] AR = after reconditioning [2] E = Eucalyptus

Table 2: Annual sawn timber estimates in m³ and Mbf for Waiakea and Hamakua State owned plantations

	Annual sawlog volume		Annual lumber output	
	m³	'000s ft³	m³	Mbf
Waiakea	23,300	820	9,300	3,950
Hamakua	44,300	1,560	17,700	7,500
Combined	67,600	2,380	27,000	11,450

Table 3: Annual pulpwood estimates in metric tonnes and US tons for Waiakea and Hamakua State owned plantations

	Annual roundwood pulpwood		Annual pulpwood residues		Total annual pulpwood	
	tonnes	US tons	tonnes	US tons	tonnes	US tons
Waiakea	10,900	12,100	9,300	10,300	20,200	22,400
Hamakua	9,800	10,800	17,700	19,500	27,500	30,300
Combined	20,700	22,900	27,000	29,800	47,700	52,700

Market Alternatives

Based on their timber properties at least three market alternatives for each species were defined. These are summarised in Table 4.

Table 4: Appropriate Products for each Species

Common name	Botanical name	Appropriate products
Rose gum	*E. grandis*	Flooring, plywood, structural sawnwood and treated poles
Swamp mahogany	*E. robusta*	Flooring, structural plywood (including LVL, face veneers)
Saligna	*E. saligna*	As for rose gum. Older material may be suitable for face veneers
Queensland maple	*Flindersia brayleyana*	Decorative veneer, panelling, mouldings, furniture and joinery
Tropical ash	*Fraxinus uhdei*	Furniture, flooring, mouldings and structural plywood
Silver oak	*Grevillea robusta*	Furniture, joinery, mouldings and decorative veneer
Toon	*Toona ciliata*	Furniture, panelling, mouldings and decorative veneer
Sugi	*Cryptomeria japonica*	Panelling, poles, fencing and light construction

Demand for Wood Products in Hawaii (excluding pulp and paper)

Domestic Market

The study attempted, through interviews and surveys, to obtain data on demand for forest products in Hawaii but the results were insufficient to support rigorous analysis. There are, therefore, no measures of production, imports exports and consumption.

The annual per capita consumption of wood and wood panels combined in the USA as a whole is about 0.63 m^3 (267 bf) and in Australia about 0.3 m^3 (127 bf). Data provided from limited sources suggested that for Hawaii it is only 0.14 m^3 (59 bf) for 1997/98. However, it seems likely, based on lifestyle comparisons with Australia and mainland USA, that total per capita consumption of wood products would be higher than this figure.

Export Demand

Three major demographic factors; population growth, urbanisation and improved living standards influence the growth in demand for forest products.

Asia will provide most of the majority of the 1.5 billion additional people in the world during the next 15 years. Currently, 60% of the Asian population is under 25; this age class represents the key emerging market for new homes, fittings and furniture.

Urban people use more industrial wood products than rural people and Asian cities are currently gaining around 50 million inhabitants per year.

Until 1997, living standards in most Asian countries were developing more rapidly than the rest of the world and it seems likely this trend will return. The supply/demand balance, cost competitiveness and availability of alternative high quality hardwoods suggest the emerging markets in Asia may provide a better opportunity for Hawaiian products than the mature markets in North America.

Annual demand for hardwood in the Asia Pacific region is around 55 million cubic metres and this is expected to grow to around 70 million cubic metres by 2010. The majority has been supplied from tropical countries where harvests are expected to decline and create opportunities for new suppliers. The main use of hardwood is for furniture (50%); housing, panelling and flooring make up a further 30%. There has been a strong trend away from exports of logs to sawn timber and semi-processed products.

Future export markets for wood products in Asia will be driven by demand (increasingly for semi-processed products) in the Japanese, Korean, Chinese and Taiwanese markets.

Prices

Table 5 gives wholesale prices in Hawaii for a selection of sawn and dried hardwoods and sugi.

The wholesale price in Hawaii is 40 to 50% below the retail price and 25 to 35% off the quoted trade price. This indicates that the wholesale price will be about $955/m³ ($2,250/Mbf) for the eucalypt species and Queensland maple and $1,380/m³ ($3,250/Mbf) for sugi and toon. Silver oak can achieve a price premium.

Table 5: Wholesale Prices in Hawaii for Sawn and Dried Hardwoods and Sugi

	PRICE	
Product	**$/m³**	**$/Mbf**
Clear oak (DAR)	2,800	6,600
Mahogany (DAR)	1,600	3,780
E. grandis, *E. robusta*, *E. saligna* and Queensland maple	955	2,250
Silver oak	1,800	4,250
Toon and sugi	1,380	3,250

NOTE: Sugi is a softwood

Higher prices for the plantation species will be achieved with further value-adding such as dressing, moulding or production of components.

Cost Competitiveness

The relative cost competitiveness of Hawaiian manufactured sawn hardwood and plywood is analysed assuming delivery to Japan. Given the immature nature of the industry in Hawaii the costs provided are not a good indication of what could be expected from a new large scale industry. The landed log cost in Australia is USD 40 - 50 and in Hawaii is USD 70 - 80. However, it will take time, investment and increasing harvest volumes before the Hawaiian industry can expect to achieve competitive cost structures. The Hawaiian unit cost of producing and distributing sawn hardwood would be the highest of the four countries analysed, i.e. Australia, Indonesia, Malaysia and Hawaii at current rates of exchange and its cost competitiveness is, therefore, least favourable. However, this disadvantage could be overcome by exploiting niche markets.

In the case of plywood, however, Hawaii would be in a more favourable position and could compete provided the annual log input to the mill is around 150,000 m³ (5.3 million ft³) which on present known volumes would be difficult. Without a much more detailed knowledge of the total resource, the possibility of delivering sufficient logs to one mill cannot be assessed. Veneer production for export could be competitive at a lower level of input.

Marketing Plan

The major issues which were raised during the study have been summarised in the context of the actions required to deal with the issues and the likely outcomes of these actions. These issues constitute the main actions required in a plan for developing and marketing plan for the Hawaii forest industry.

Action Summary

ACTIONS	OUTCOMES
▪ State wide inventory of standing timber on all islands containing commercial stands. All potentially important commercial species should be identified and inventoried, e.g. *Eucalyptus microcorys* on the Hamakua coast. Quality, as well as quantity, should be assessed.	▪ Area and volumes of commercial timber. ▪ Inventory of species worthy of further development ▪ Investors can determine if there is enough wood within economic hauling distance of a proposed processing plant. ▪ Investors can determine the size of processing plants according to the resource available. ▪ Investors can decide the most appropriate type of processing plant and product for the resource available.
▪ Investigate the potential for expanding the resource base and assessing how likely it is that such an expansion will occur.	▪ Potential to expand the industry and gain increased economic development for the state. ▪ Allows long term predictions of development to be made.
▪ Government assistance in the development of commercial forestry and forest industries in Hawaii includes support for species and provenance trials and infrastructure for industry	▪ Improved productivity from plantations. ▪ Provision of additional infrastructure to improve competitiveness.
▪ Assess the durability of each of the species for various hazard levels and modes of attack and determine appropriate preservative treatments.	▪ Guarantee of durability under specified hazard levels. Most efficient use of the resource - consumer confidence in local products
▪ Establish internationally acceptable grading rules for both appearance and structural grades of lumber. The advice and assistance of National Hardwood Lumber Association should be sought.	▪ Production of commonly accepted commercial grades in a consistent manner. ▪ Cost efficient conversion of logs to a range of graded sawn products.
▪ Define appropriate drying schedules and techniques under Hawaiian conditions.	▪ Production of well seasoned sawn timber to meet market requirements - consumer confidence in local products.
▪ Statewide forest products market survey.	▪ Improved understanding of the local market and requirements. ▪ Opportunities for local grown and processed products. ▪ Informed forestry and forest industry development.
▪ Investigation of export markets for Hawaiian forest products including cost competitiveness studies. ▪ Review option of joining American Hardwood Export Council	▪ Controlled, informed and profitable penetration of export markets. ▪ Indication of likely margins for producers and selling agents. ▪ Leverage from AHEC's extensive and highly successful marketing efforts yielding cost effective marketing.
▪ Publication of quarterly production, import, export and consumption statistics for forest products in Hawaii.	▪ Informed industry and government.
▪ Promotion of the Industry through: – Brochures, technical literature, newsletters, samples, participation in trade shows, web sites – Targeted marketing which has identified customers and assessed their needs and then provides that market with a supply to meet these needs.	▪ Industry recognition and expansion. ▪ Raises industry profile with potential growers, investors, processors, government and product buyers.

1. Species Descriptions

1.1 Introduction

Eight species of Hawaiian grown timber are described in this report. Separate species description sheets have been included to provide information on the physical and mechanical properties of these timbers including:

- General description of the species
- Colour of the timber
- Grain
- Texture
- Working properties
- Seasoning characteristics
- Shrinkage
- Durability including resistance to termite attack and treatability
- Strength group
- Characteristic defects
- Lyctus susceptibility and,
- Common uses.

All technical terms and numerical codes are defined in Sections 1.3 to 1.14

1.2 Definition and Discussion of Terms

The eight species in this report have been characterised in some detail in separate information sheets. Table 1-9 has been drawn up to provide information on the physical and mechanical properties for each species. However, these information sheets and Table 1-9 may contain a number of expressions with which the reader may not be familiar.

Definitions of the terms used are provided in this section and these should be read in conjunction with the information sheets and Table 1-9.

1.3 Softwoods and Hardwoods

Wood is frequently referred to as either a *softwood* or a *hardwood*. This may not coincide with whether a wood is physically hard or soft but is, in fact, a major botanical distinction. For this study we are concerned with only one softwood species of commercial importance, sugi, the rest are hardwoods.

Hardwoods are distinguished from softwoods by having a more complex anatomy, a major distinction being that hardwoods are pored, i.e. they have ‘vessels’, as well as fibres. These vessels may look like holes in a cross-section of the wood; they are sometimes large enough to be seen with the naked eye (as in toon) and can generally be seen through a hand lens (x10) if the surface is cut smoothly with a razor. Quite frequently the vessels are blocked by tyloses, especially in the heartwood, so that they are no longer visible as holes. However, their shape and distribution can still be seen. As another source of confusion, hardwoods are also referred to as ‘broad-leaved’ species. However, some hardwoods such as *Casuarina equisetifolia* (beach she-oak known as ironwood in Hawaii) have needle-like foliage.

1.4 Sapwood, Heartwood and Juvenile Wood

In the tree, *sapwood* is living wood, active in the vital processes of the tree. *Heartwood*, which at some stage was sapwood, is dead, even in the living tree. The distinction between sapwood and heartwood is also very important in practice. For example, sapwood of any species, once the tree is felled, is regarded as non-durable while the heartwood of some species is durable. Non-durable sapwood, which is sufficiently permeable, may be treated with preservatives to confer durability, but some non-durable heartwood may be untreatable. However, durability has a particular meaning which will be discussed later.

Juvenile wood is low quality wood which occurs in the core of the tree. In some trees it may have virtually disappeared through attack by decay, fungi and termites, but in others it may still be present. It is often of low density and strength and may warp severely during seasoning, largely because of spiral grain.

1.5
Early and Latewood

Wood produced in the first part of the growth season is commonly referred to as earlywood. As growth slows down later, the wood produced is then referred to as latewood. In northern temperate climates, earlywood is often referred to as springwood, latewood as summerwood. This nomenclature is, however, inappropriate for trees growing in more tropical climates.

Earlywood has fibres which are relatively large in diameter, short in length and thin walled. In latewood, the fibres become smaller in diameter, longer in length and have thicker walls. Thus the latewood is denser than the earlywood and looks darker; a difference which, especially on a cleanly cut end grain surface, is often visible to the naked eye as growth rings. Some species produce growth rings which are not readily visible except when using a hand lens or microscope. Other species, where growth conditions vary little throughout the year, e.g. in equatorial rainforest, may show no growth rings.

Growth rings are sometimes referred to as annual rings and, in some species, this is perfectly valid. However, some species may produce more than one growth spurt in a single year, in which case there could be more than one growth ring in that year. Eucalyptus are particularly likely to do this; they normally respond opportunistically when growing conditions are good, then slow down their growth when conditions are less favourable. This could happen two to three times in one year or, alternatively, in severe and prolonged drought conditions, only once in two or three years.

1.6
Colour in Wood

The basic chemical components of wood, i.e. cellulose, lignin and hemi-celluloses do not give it colour. The colour in wood is caused by complex compounds known generically as extractives. These are extraneous chemicals deposited either in the cavities of the wood or within the wood substance, particularly during the transformation of sapwood to heartwood. Some of these extractives give no colour to the wood, but others, for example two groups of chemicals known as flavones and quinones, do. When wood is exposed to sunlight for a long time the colour changes because the extractives change. Whitish and cream coloured wood becomes yellowish, and red woods become brown. Such colour changes occur at the wood surface only and the original colour can be regained by sanding or planing the surface.

Heartwood, because it contains many more extractives, is generally much more coloured than sapwood.

The colour of wood will also change if it is exposed, not just to sunlight, but to all the elements of weathering, e.g. sunlight, rain, dew, wind, snow and hail. Dark coloured wood becomes paler through leaching of extractives at the surface and chemical bleaching; light coloured wood tends to darken through oxidation of extractives. Eventually, however, all wood exposed to the weather becomes more or less grey. This again is a surface phenomenon and the grey can be removed by sanding or planing.

1.7 Grain, Texture and Figure

Grain and texture are frequently confused. Grain refers to the general direction of the fibres in the wood relative to the main axis of the tree from which the wood comes.

In straight grained timber, the fibres run parallel to the longitudinal surface of the log. If a straight grained log is taper sawn, then the timber derived from it should be straight grained. If, however, the log has a pronounced taper and is sawn parallel to its centre line, the timber derived from it will have sloping grain.

Interlocked grain is characterised by periodic changes or reversals in the angles of the fibres in adjacent layers of wood. Interlocking the bent fingers of both hands together gives some idea of the way in which interlocking grain can occur.

Wavy grain is produced when the fibres are arranged in waves or ripples.

Spiral grain (very common in the juvenile wood of plantation grown softwoods) occurs when the fibres spiral around the axis of the tree.

Thus grain does not refer specifically to the appearance of a piece of wood but rather to the way in which fibres are laid down in relation to each other.

Figures 1-1 to 1-3 illustrate the appearance of the end grain of a sawn board if growth rings are visible. Quartersawn implies sawing more or less in the radial direction; backsawn implies sawing more or less tangential to the growth rings; mixed-sawn is intermediate between the two.

Figure 1-1: End grain of a quartersawn board

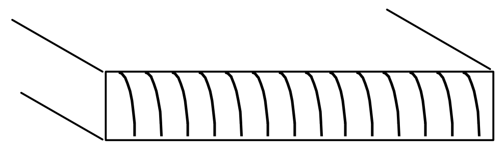


Figure 1-2: End grain of a backsawn board

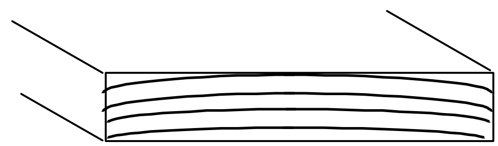
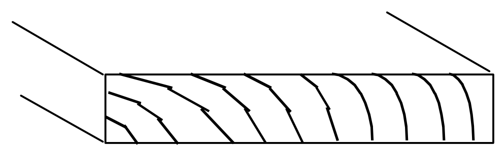


Figure 1-3: End grain of a mixed sawn board



Texture is described as being even or uneven, fine, coarse or medium and is determined by the size and arrangement of the cells and by variations in density such as occur between latewood and earlywood. A coarse textured wood is characterised by relatively large cells or wide growth rings, a fine textured wood by relatively small cells or narrow growth rings. Even texture implies that these size relationships remain much the same throughout the wood; uneven texture implies that there are variations in these size relationships within the wood. Texture, unlike figure, does not depend on how the wood is sawn.

Figure refers to the appearance of a dressed surface of wood, arising from the arrangement of various wood tissues, e.g. rays, growth rings and grain irregularities, even the presence of abnormal tissue e.g. burls, and from variations in colour. Figure will vary depending on how the log is sawn, i.e. quartersawn, backsawn or mixed-sawn. For example, in *Grevillea robusta* quartersawn timber has a more contrasting figure than back sawn because of the presence of broad medullary rays.

1.8 Seasoning and Moisture Content

1.8.1 Moisture content

All newly felled trees contain a large amount of water, most of which has to be removed by seasoning for most applications.

A piece of wood is made up of many millions of small cells most of them tube-like in structure. Water occurs in both the cell spaces (lumens) and the cell walls. The former is known as *free* water; the latter as *bound* water, because it is absorbed into the wood substance of the cell wall. We commonly use the expression *percentage moisture content* (% mc) to define how much of both kinds of water a piece of wood contains. Two definitions are used, one by wood scientists and technologists and by the timber trade, the other by the pulp and paper industry. In this report only the first definition will be used. However, both are defined below.

i. $$\%\ \text{mc of wood} = \frac{\text{mass of water}}{\text{Oven dry mass of wood}} \times 100$$

ii. $$\%\ \text{mc of wood} = \frac{\text{mass of water}}{\text{Oven dry mass of wood + mass of water}} \times 100$$

Percentage moisture content (% mc) can be determined most accurately by taking a small sample piece of wood, weighing it and then putting it in an oven at 103°C until it loses no more mass between two successive weighings. This may take about 24 hours. However, the last two weighings may be only an hour apart. Since % mc can vary significantly within a single piece of wood of commercial size, it may be necessary to use several small samples to assess this variability and to get some idea of moisture distribution.

If the mass of wood + water (i.e. the initial mass) = x grams

and the mass of wood after oven drying = y grams

then the % mc according to i. = $\frac{100\,(x - y)}{y}$

and the % mc according to ii. = $\frac{100\,(x - y)}{x}$

Example

If x = 249.5 g and y = 109.3 g

then $mc_1 = \frac{100\,(249.5 - 109.3)\%}{109.3}$

$= 128.3\%$

and $mc_2 = \frac{100\,(249.5 - 109.3)\%}{249.5}$

$= 56.2\%$

Moisture contents determined by either i. or ii. above are easily convertible:

$$mc_2 = 100 \left(\frac{mc_1}{mc_1 + 100} \right)$$

If one is known, the other can be determined. However, following timber trade practice, we shall use only mc_1.

Oven drying wood to determine its moisture content takes time and, for wood which is less than 25% mc, we have moisture meters which can read the mc directly, usually to within 1% or 2% accuracy. These meters, because they actually measure electrical resistance not moisture content, have to be calibrated to read moisture content directly (mc_1) and are normally calibrated against a northern hemisphere species, commonly Douglas fir. This means that, for the species in the Hawaiian study, correction factors have to be determined.

Table 1-1 gives these correction factors for some of the species, assuming the meter is calibrated for Douglas fir. For the species not included, the correction factors are unknown.

The data provided must be used cautiously if accurate mc's are required. Some of the species are not well documented and some data have been taken from trees grown in conditions similar to but not exactly replicating those found in Hawaii. When in doubt oven drying, as described above, should be used.

1.8.2 Removal of water during seasoning

The moisture content of trees varies greatly, ranging, for example, from about 35% in the heartwood of an old, high density hardwood to as much as 200% in the outer sapwood of a young fast-growing plantation species of much lower density. Even within a single tree there may be considerable differences in some species. However, once a tree is felled and cut up it begins to lose moisture, its free water first. When all the free water has left the wood and only bound water remains the wood is said to be at fibre saturation point, corresponding to a moisture content of about 30%. The wood will, however, continue to lose bound water and, if it is in the open air, will eventually reach an air-dry moisture content which is in equilibrium with the environment. The wood is then seasoned. The actual air-dry moisture content varies according to the locality and weather conditions; in humid coastal conditions in Australia, it will be several percent higher than in the dry, inland regions; for example, about 15% to 20% in the former compared with about 7% to 12% in the latter. In Hawaii, there will be very substantial variations between the wet side and dry side of the islands.

In buildings there will be further variations in moisture content. In Hawaii the major impact will be from air conditioning since this reduces relative humidity, hence the equilibrium air dry moisture content of wood in air conditioned atmospheres. This moisture content may be as low as 6 to 8%.

Table 1-1: Corrected moisture contents for Hawaiian grown species when using a moisture meter calibrated for Douglas fir

METER READING		**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Common Name	**Botanical Name**	**Corrected moisture content**																		
rose gum or flooded gum	*Eucalyptus grandis*	8	9	10	11	12	13	14	14	15	16	17	18	18	19	20	21	22	23	24
Sydney blue gum or saligna	*Eucalyptus saligna*	8	9	10	11	12	12	13	14	15	15	16	17	18	19	19	20	21	22	23
swamp mahogany	*Eucalyptus robusta*	No information available for swamp mahogany. Nearest equivalent is probably southern mahogany (see below)																		
tropical ash	*Fraxinus uhdei*	no information available																		
Queensland maple	*Flindersia brayleyana*	9	10	10	11	12	13	14	15	16	17	18	18	19	20	21	22	23	24	24
southern silky oak	*Grevillea robusta*	7	7	8	9	9	10	11	11	12	13	13	14	15	15	16	17	17	18	19
Australian red cedar	*Toona ciliata*	8	9	10	11	12	13	14	16	17	18	19	20	21	22	23	25	26	27	27
Sugi	*Cryptomeria japonica*	No information available																		
southern mahogany*	*Eucalyptus botryoides*	7	8	9	10	11	12	12	13	14	15	16	17	18	19	20	20	21	22	23

Source: Testing timber for moisture content, CSIRO Special Report, Melbourne, 1974
* southern mahogany used as similar timber to swamp mahogany.

1.8.3 Equilibrium moisture content and hygroscopic movement

The above discussion indicates there are possible variations in the moisture content of air-dry timber depending on environmental conditions, particularly the relative humidity of the air. This leads us to the concept of equilibrium moisture content (emc), which, as the name implies, is the moisture content at which a piece of wood is in equilibrium with its surroundings. However, environmental conditions are usually changing so that the emc will also change. If the relative humidity of the air, for example, goes up, the moisture content of the wood will also go up to establish a new equilibrium and vice versa. Table 1-2 gives some typical values for the emc of wood at a temperature of 21°C when the relative humidity is changed and the wood is given sufficient time to adapt to the change.

Table 1-2: Equilibrium moisture content

Atmospheric relative humidity (%)	emc of wood (%)
30	6.0
42	8.0
65	12.0
80	16.1
90	20.6

If the moisture content goes up, the wood swells, if it goes down, the wood shrinks; this complex phenomenon in wood is known as hygroscopic movement. A time lag is involved because wood does not respond instantly to environmental change so that diurnal changes in wood moisture content are quite small. However, seasonal changes can be quite large - sufficient to create problems in practice, especially if there are large seasonal changes in relative humidity. It is worthwhile, therefore, for most timber uses, to season down to an average moisture content which will be midway between the upper and lower moisture contents anticipated in service, thus minimising subsequent hygroscopic movement. Where, in the species information sheets, a particular species is said to be stable, this implies that the hygroscopic movement is low.

1.9 Density of Wood

The density of wood can be expressed in three ways the unit being either g/cm^3 or kg/m^3 in the metric system or lb/ft^3. These are:

$$\textit{Green density} = \frac{\text{Mass of green wood}}{\text{Volume of green wood}}$$

$$\textit{Air-dry density} = \frac{\text{Mass of wood in the air-dry condition}}{\text{Volume of wood in the air-dry condition}}$$

$$\textit{Basic density} = \frac{\text{Mass of oven-dry wood}}{\text{Volume of green wood}}$$

Green density

Green density is a useful value to know when transporting or otherwise handling freshly felled wood. However, as discussed previously, wood begins to lose moisture as soon as it is felled; thus the green density begins to drop. Also the moisture content of green wood can itself vary greatly, again as discussed above. Thus, green density may be a useful practical ratio, especially if the moisture content is known, but it is not useful scientifically. However, most green densities are centred around 1 tonne per m^3 or 62.5 lbs per ft^3.

Air-dry density

Air-dry density is also a useful practical ratio, but again not much use scientifically since the air-dry moisture content depends on where you are. Conventionally, in Australia air-dry moisture content is defined as 12%. In Hawaii, 15% or 16% would be a more useful value. Thus, because the equilibrium air-dry moisture content in Hawaii would be higher than in Canberra, Australia, for example, the same piece of wood will have a higher air-dry density in Hawaii than in Canberra, although there could be an offset to this difference since wood swells as it absorbs moisture from the air.

The species information sheets give densities by class from 1 to 10+. These are shown in Table 1-3 and are for air-dry density at 12% moisture content.

Table 1-3: Density classification

Class	Density (kg/m³)	lb/ft³
1	<160	<10
2	160 - 199	10 - 12.4
3	200 - 259	12.5 - 16.2
4	260 - 319	16.3 - 19.9
5	320 - 359	20 - 22.4
5+	360 - 399	22.5 - 24.9
6	400 - 449	25 - 28
6+	450 - 509	28.1 - 31.8
7	510 - 569	31.9 - 35.5
7+	570 - 639	35.6 - 39.9
8	640 - 719	40 - 44.9
8+	720 - 799	45 - 49.9
9	800 - 899	50 - 56.1
9+	900 - 1,009	56.2 - 63
10	1,010 - 1,139	63.1 - 71.1
10+	>1,139	>71.1

Basic density

Wood does not exist in a condition in which its basic density can be directly measured as such. However, it is a useful scientific unit since the oven-dry mass of a piece of wood and the green (water saturated) volume of that same piece of wood are reproducible, although not simultaneously. Basic density is also a very useful practical unit since a number of important physical and mechanical characteristics of wood can be related to its basic density statistically. As discussed in Section 1.12, basic density may be used in allocating a temporary strength group when other information is not available.

Numerically basic density in g/cm³ gives the same result as wood specific gravity (commonly used for scientific work in the USA). However, specific gravity is the ratio of oven dry mass of a given swollen volume of wood to the mass of an equal volume of water at 4°C. In Australia, basic density is the favoured unit since it is easier to understand.

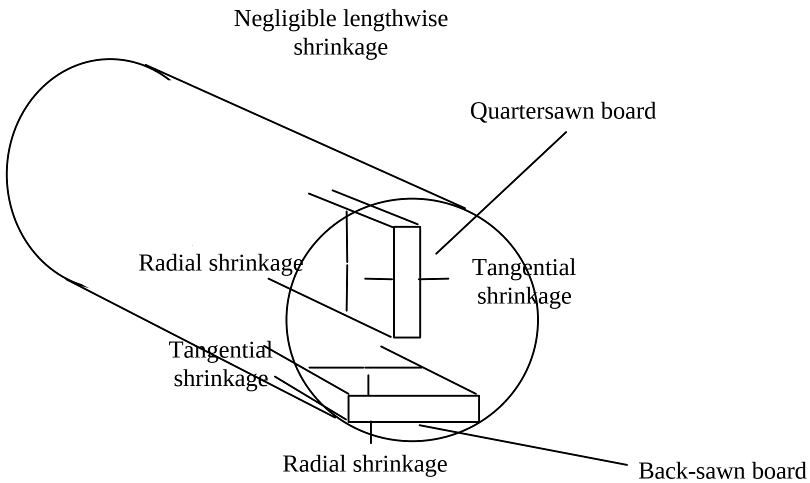
1.10 Shrinkage

Wood shrinks as it seasons, particularly after it reaches fibre saturation point (fsp) (about 30% moisture content) and continues to dry down to its final moisture content. This is described as normal shrinkage. Sometimes serious abnormal shrinkage, accompanied by internal checking or splitting occurs above fsp as a result of cellular collapse.

Normal shrinkage is a permanent characteristic of wood. Abnormal shrinkage is not. If during drying abnormal shrinkage occurs, it can be largely eliminated by steaming the wood, a process known as reconditioning. Thus, in the species description sheets, shrinkage may be stated as BR or AR (Before Reconditioning and After Reconditioning). BR will invariably be larger than AR. Whatever the form of shrinkage, it is always expressed as a percentage of the green dimension.

Wood is an anisotropic material, i.e. its properties change according to the direction in which they are measured. Normal shrinkage occurs, anisotropically. In the grain direction, i.e. parallel and lengthwise to the bole of the tree, normal shrinkage is negligible. However, radial and tangential shrinkage are usually significant in most species. Radial shrinkage, as its name suggests, is a transverse phenomenon and follows the orientation of the ray tissue. Tangential shrinkage is, for all practical purposes at right angles to radial shrinkage and is usually between 1.5 and 2.5 times as great as radial shrinkage. In trees with growth rings, tangential shrinkage is parallel to the transverse orientation of the growth rings, radial shrinkage is at right angles to the growth rings. Figure 1-4 illustrates the three major shrinkage directions.

Figure 1-4: The three major shrinkage directions



In a fully quartersawn board tangential shrinkage is equivalent to shrinkage in the thickness of the board; radial shrinkage to shrinkage in width and vice versa in a backsawn board. In a mixed-sawn board, there will be components of tangential and radial shrinkage in both thickness and width.

Volumetric shrinkage % is virtually equivalent to % tangential + % radial shrinkage, e.g. for *Eucalyptus robusta*, tangential shrinkage is 9% and radial shrinkage 7%, so that volumetric shrinkage is about 16%.

1.11 Lyctus Susceptibility

Lyctus beetles are commonly referred to as powder-post beetles or borers, but since bostrychid beetles are also given the same common name, it is better to distinguish them. We shall refer to the former as lyctids.

Lyctids attack the sapwood of susceptible hardwoods after drying down to between 8% and 25% moisture content. Generally speaking, tree species are either susceptible or not (depending on whether the wood contains enough starch, and whether the vessels are large enough for egg laying by the adult female beetle). Softwoods are not attacked by lyctids.

Of the 8 species listed in the information sheets, 6 are susceptible to attack by lyctids. Durability, to be discussed in Section 1-12 does not correlate with resistance to attack by lyctids. Many durable species can be attacked by lyctids.

In Queensland and New South Wales, legislation controls the marketing of wood and wood products containing lyctus susceptible species. The relevant Act in each State requires that products such as furniture, mouldings, joinery, flooring, panelling, cladding, plywood and laminated wood must not contain susceptible sapwood unless it has been treated with an approved preservative. The New South Wales Act does permit framing timber, which will be out of sight in a finished building, to have up to 25% of its perimeter in untreated susceptible sapwood. Such sapwood will be attacked within the first two years of construction and the householder may become aware of this through round flight holes 0.03-0.06 inches (0.75-1.5 mm) in diameter in linings such as plasterboard covering the framing timbers. However, there is usually no cause for serious alarm; the holes can be filled and the structural integrity of the house is not affected.

1.12 Durability

Wood can be destroyed by weathering, decay, insect attack and fire. However, sound, seasoned heartwood can last indefinitely if it is protected from fire, the weather and mechanical damage and is out of the ground and kept dry (i.e. below 20% mc).

Australia has a durability classification based on experience and field and laboratory testing which assigns durability ratings to a whole range of species of timber.

Sapwood is regarded as non-durable for most species. However, it must be emphasised that some sound seasoned sapwood, though not all, e.g. lyctus susceptible species, can also last indefinitely if it is protected as described for heartwood above and, in addition, is protected from attack by termites and borers.

For felled wood, durability ratings give an indication of how long the heartwood of a particular species will last when in contact with the ground and thus exposed to attack either by decay only or by decay and termites. However, there are large variations in durability, not only between species but also within a single species and even within a single tree so that durability ratings are far from precise. Furthermore, environmental conditions may have a profound influence so that a species that is durable in temperate parts of Australia may not be so in more tropical areas, e.g. Hawaii. Table 1-4 gives some indication of variations in durability arising from locality differences.

Durability is conferred on heartwood by the chemical extractives deposited within the wood, mainly during its transformation from sapwood to heartwood. Variations in durability can be accounted for by variations in the amount of extractives deposited and their chemical composition.

Table 1-4: Durability classification

		Expected average life in the ground (years)	
Species class	**Rating**	**Southern Australia**	**Northern Australia**
1	Highly durable	¤21	¤14
2	Durable	12-25	5-14
3	Moderately durable	8-15	2-7
4	Non-durable (perishable)	1-9	1-3

Southern Australia is south of about 30° latitude.

Of the Hawaiian grown species described in the information sheets, none are in Class 1 or 2, *Eucalyptus robusta*, *Flindersia brayleyana* and *Cryptomeria japonica* are intermediate between Class 2 and 3, *E. saligna* and *E. grandis* are Class 3, *Grevillea robusta* is intermediate between Class 3 and 4, and *Fraxinus uhdei* is Class 4. In Australia *Toona ciliata* is classed as 2-3 but in Hawaii is only 4.

In general, Hawaii has few durable species that have been grown in plantations. To ensure a longer life in hazardous situations, treatment with preservatives, at least of the sapwood, is essential. Treatability is a complex phenomenon and the reader is referred to the information sheets for guidance about wood from plantations.

Because of the importance of termites in Hawaii, these have been dealt with separately in the Individual Species Descriptions (Section 1.15).

NOTE: CSIRO has produced a revised natural durability classification (In Ground Durability Ratings for Mature Outer Heartwoods, 1996) but this has not yet been accepted. The old classification system has, therefore, been retained for this report.

1.13 Strength Grouping

One of the most important end uses for timber is as a structural material.

A system of strength grouping has been developed by CSIRO Australia and is designed to assist in marketing and in the appropriate use of timber for structural purposes. Each species is assigned to one of seven or eight strength groups depending on whether it is being used green or seasoned. Green timber has seven strength groups (S1 to S7); seasoned timber has eight strength groups (SD1 to SD8).

Table 1-5 gives the mean minimum standard test values of bending strength (modulus of rupture), stiffness (modulus of elasticity), compression parallel to the grain (maximum crushing strength) for green material in each of these groups. Table 1-6 gives the same values for seasoned timber. All strength values quoted are based on testing of small clear specimens. These values vary between plantation grown and native trees as noted in the individual species descriptions 1.15.1 to 1.15.8. The techniques used in strength grouping have been documented by Standards Association of Australia (1979). The standard is currently under review.

Table 1-5: Mean minimum standard strength values (based on small clear specimens) for green timber

	PROPERTIES					
Strength group	**Modulus of rupture (MPa) †**	**lbf/in^2**	**Modulus of elasticity (GPa)**	**lbf/in² x 1000**	**Maximum crushing strength (MPa)**	**lbf/in²**
S1	103	14,935	16.3	2,363	52	7,540
S2	86	12,470	14.2	2,059	43	6,235
S3	73	10,585	12.4	1,798	36	5,220
S4	62	8,990	10.7	1,551	31	4,495
S5	52	7,540	9.1	1,319	20	2,900
S6	43	6,235	7.9	1,145	22	3,190
S7	36	5,220	6.9	1,000	18	2,610

Table 1-6: **Mean minimum standard strength values (based on small clear specimens) for timber at 12% mc**

	PROPERTIES					
Strength group	**Modulus of rupture (MPa) †**	**lbf/in^2**	**Modulus of elasticity (GPa)**	**lbf/in^2 x 1000**	**Maximum crushing strength (MPa)**	**lbf/in^2**
SD1	150	21,750	21.5	3,045	80	11,600
SD2	130	18,850	18.5	2,610	70	10,150
SD3	110	15,950	16.0	2,320	61	8,845
SD4	94	13,630	14.0	2,030	54	7,830
SD5	78	11,310	12.5	1,740	47	6,815
SD6	65	9,425	10.5	1,450	41	5,945
SD7	55	7,975	9.1	1,305	36	5,220
SD8	45	6,525	7.9	1,015	30	4,350

1 megapascal = 1 N/mm^2 = 145 lbf/in^2
lbf = pounds force

As stated above, the strength groupings given in Tables 1-5 and 1-6 are based on testing of small clear samples. Commercial sizes of timber will usually have defects which will affect their strength. Thus allowances have to be made for the presence of defects when assessing the "stress grade" of a particular piece of timber. A set of visual grading rules and capacity to perform as a structural member in service provides limits on the size and number of defects permitted within each visual grade and also defines the strength reducing effect of the defect based on a percentage of the strength of clear material. This strength reducing effect is also based on test results. However, strength grouping is the starting point and, from the point of view of marketing structural timber and safety in its use, it is essential the species can be classified in a strength group as precisely as possible. Tables 1-7 and 1-8 show the relationship between strength groups, visual grades and stress grades for green and seasoned timber respectively.

Table 1-7: Relationship between strength group, visual grade and stress grade for green timber

Visual grade *	Percent strength of clear material	STRENGTH GROUP S1	S2	S3	S4	S5	S6	S7
		Stress grade						
Structural Grade No. 1	75	F27	F22	F17	F14	F11	F8	F7
Structural Grade No. 2	60	F22	F17	F14	F11	F8	F7	F5
Structural Grade No. 3	48	F17	F14	F11	F8	F7	F5	F4
Structural Grade No. 4	38	F14	F11	F8	F7	F5	F4	F3

* Australian Standard AS 2082-1979, Visually Stress-Graded Hardwood for Structural Purposes.

Table 1-8: Relationship between strength group, visual grade and stress grade for seasoned timber

Visual grade *	Percent strength of clear material	STRENGTH GROUP SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8
		Stress grade							
Structural Grade No. 1	75		F34	F27	F22	F17	F14	F11	F8
Structural Grade No. 2	60	F34	F27	F22	F17	F14	F11	F8	F7
Structural Grade No. 3	48	F27	F22	F17	F14	F11	F8	F7	F5
Structural Grade No. 4	38	F22	F17	F14	F11	F8	F7	F5	F4

* Australian Standard AS 2082-1979, Visually Stress-Graded Hardwood for Structural Purposes, Australian Standard AS 2858-1986, Timber-Softwood, Visually stress graded for structural purposes.

Using Tables 1-7 and 1-8 is straightforward. If, for example, a piece of unseasoned *Eucalyptus saligna* (saligna) is to be used structurally, and it is visually graded correctly as Structural Grade No. 2 then, because it is assigned to Strength Group S3, the stress grade of that particular piece is F14. If now, a piece of unseasoned *Fraxinus uhdei* (tropical ash) is also visually graded as Structural Grade No. 2 then, because it is assigned to Strength Group S5, the stress grade of that particular piece is F8, i.e. a lower grade than the saligna.

When using properly seasoned timber structurally, the strength group will change. The seasoned strength group is unknown for some of the species under study; e.g. *Fraxinus* and *Toona*. For these species, therefore, it would be prudent to go from S5 to SD6 and S7 to SD8 respectively. This still means that seasoned timber of either species will have a higher stress grade than unseasoned timber of the same species and the same visual grade and will have the additional advantage that it has completed its shrinkage from

Hawaii species under study.

It appears that, to date, Hawaii has not developed a uniform system of

make best use of the strength grouping system, the Australian system should be used. This is documented in Australian Standard 2082-1979, "Visually

Standard should be purchased from the Standards Association of Australia, PO Box 458, North Sydney 2059 (Fax No.: 02-9959 3896).

Some Mechanical Properties of Wood

Introduction

Table 1.9 can only be used as broad guidelines since they only apply to clear timber of specified dimensions tested in the laboratory under standardised

Modulus of rupture, modulus of elasticity and maximum crushing strength are, however, used in deciding which strength group to assign to a particular

structural timber.

1.14.2 Modulus of rupture (mor)

The mor is one of a series of mechanical properties determined under

strength in static bending of a sample of defect free specimens of the species when loaded as a beam. It does not, of course, give strength values for all

reducing effect and, in seasoned timber, temperature and moisture content will also affect strength. For example, for every 1% increase in moisture

effect is clearly shown by the differences between mor green and mor dry.

1.14.3 Modulus of elasticity (moe)

Moe, like mor is determined in the laboratory and is a measure of the

beam. Similar general conditions apply to the interpretation of moe as to mor except that the effect of moisture content is less pronounced, i.e. for every

1.14.4 Maximum crushing strength (mcs)

Mcs is again determined in the laboratory by compressing small clear samples parallel to the grain and is a measure of the resistance of wood to failure, or the strength of wood, when loaded as a column. Similar general conditions apply to the interpretation of mcs as to mor and moe, except that a change in moisture content may exercise an even more marked effect in some species. Although this doesn't always apply, it would be safer to assume that, in dry timber, for every 1% increase in moisture content, the mcs decreases by 6%.

1.14.5 Izod value

The Izod value is a measure of resistance to the impact of sudden shock loads. There is, in fact, a linear relationship in green timber between Izod value and basic density ($r^2 = 0.62$) (random selection of 27 species). However, the relationship for dry timber of the same species is much less obvious ($r^2 = 0.43$). Furthermore, there is no consistent relationship for changes in moisture content from green to dry. Sometimes the Izod value increases in the dry timber, sometimes it decreases, less often the Izod value doesn't change.

1.14.6 Janka hardness

Janka hardness measures the resistance of wood to denting. Hardness in dry timber is generally higher than in green timber though not invariably so.

1.14.7 Physical and mechanical properties for Hawaiian grown timber species

Tables 1-9 and 1-10 summarise the physical and mechanical properties of the Hawaiian grown timbers.

Table 1-9 Physical and mechanical properties of Hawaiian grown species - US units

	Density in lb/ft^3					mor (lbf/in)		moe (lbf/in (x 10^5))		mcs (lbf/in)		Izod (ftlbf)		Janka (lb/f)	
	Green	Air dry	Basic	Strength group (green)	Strength group (dry)	Green	Dry	Green	Dry	Green	Dry	Green	Dry	Green	Dry
Eucalyptus robusta		49 - 51.3	44.4	S4	(SD5)				16000		10500		7.4 rad		2010 rad
Eucalyptus saligna	66.8	53.1	40.6	S3	SD4	13195	20300	23200	26100	6380	9860	11.8	13.3	1439	2023
Eucalyptus grandis	59.3	38.7	31.8	S3	SD4	11455	17690	18850	24650	2220	9570	11.1	11.8	1191	1686
Grevillea robusta	68.7	38.7	32.5	S5-S6	(SD6)		13340		13400		5800				832
Flindersia brayleyana		36.2	27.5	S6	SD6		10020 - 11194		14500		6300 - 7100		8.1 rad		1057
Toona ciliata	39.9	26.2	21.8	S7	(SD8)	6815	9425	13050	13650	3625	5220	3.7	4.1	472	517
Cryptomeria japonica		20.3 - 22.5		Up to S7	SD8		7119 - 8000		7750-8600		4016 - 4500				
Fraxinus uhdei				S5	(SD6)										

( ) Preliminary only. The species need further testing.

Table 1-10: Physical and mechanical properties of Hawaiian grown species - Metric units

	Density in kg/m³					mor (MPa)		moe (GPa)		mcs (MPa)		Izod (joule)		Janka (Kn)	
	Green	Air dry	Basic	Strength group (green)	Strength group (dry)	Green	Dry	Green	Dry	Green	Dry	Green	Dry	Green	Dry
Eucalyptus robusta		785 - 822	711	S4	(SD5)				11		72.4		10 rad		8.9 rad
Eucalyptus saligna	1070	850	650	S3	SD4	91	140	16	18	44	68	16	18	6.4	9
Eucalyptus grandis	950	620	510	S3	SD4	79	122	13	17	36	66	15	16	5.3	7.5
Grevillea robusta	1100	620	520	S5-S6	(SD6)		92		9.2		40				3.7
Flindersia brayleyana		580	440	S6	SD6		69.1-77.2		10		43.5-49		14.9 rad		4.7
Toona ciliata	640	420	350	S8	(SD8)	47	65	9.0	9.4	25	36	5.0	5.5	2.1	2.3
Cryptomeria japonica		325-360		Up to S7	SD8		49.1-55.2		5.3 - 5.9		27.7-31				
Fraxinus uhdei				S5	(SD6)										

( ) Preliminary only. The species need further testing.

1.15 Individual Species Descriptions

1.15.1 Eucalyptus grandis (rose gum)

Species	:	*Eucalyptus grandis* (rose gum or flooded gum)

Family	:	Myrtaceae	
General description	:	Hardwood; Density Class 8+ (Australia - native) Class 7+ (South Africa and Malaysia - plantation); Grows 150 - 200 ft (45 - 60 m), DBH range 3' - 6'6'' (1-2 m)	
Colour	:	Heartwood dark pink to red brown with a pink tinge, depending on age and area of origin	
Grain	:	Straight or interlocked	
Texture	:	Moderately coarse but even	
Working properties	:	Timber from younger trees works easily, old material may produce some surface woolliness and have a tendency to splinter. Generally free from defects, takes a good polish, but tends to split when nailing	
Seasoning characteristics	:	Varies from being easy to moderately difficult to season, but surface checking can be avoided by carefully controlling drying conditions in the early stages. Cupping may occur in backsawn boards but can be removed by a reconditioning treatment. Warping not common except in timber from fast grown trees.	
Shrinkage	:	4% radial, 5% tangential BR* 3.4% radial, 5.2% tangential AR*	
Durability	:	Class 3	
Strength group	:	S3 (native), S4 (plantation) SD4	
Characteristic defects	:	Timber very prone to marine borer attack	
Termites and treatability	:	Very prone to termite attack. Sapwood can be treated with preservative but heartwood is resistant.**	
Lyctus susceptibility	:	Not susceptible	
Common uses	:	structural timber (heavy and light) flooring boat building cabinet work and furniture veneer plywood	pulpwood interior trim hardboard/particleboard poles craftwood mouldings

*BR & AR = Before and After Reconditioning (See Section 1.11)

** Information on termites and treatability has been drawn from numerous sources. However, the most important single reference is: Characteristics Properties and Uses of Timbers, South east Asia; Northern Australia and the Pacific by W.G Keating and Eleanor Bolza (Volume 1), published by Inkata Press, Melbourne, Sydney and London.

1.15.2 Eucalyptus robusta

Species	:	*Eucalyptus robusta* (swamp mahogany)

Family	:	Myrtaceae
General description	:	Hardwood; Density Class 9 (Australia - native) Class 8 (Hawaii plantation); Grows 60 - 90 ft, (18 - 27 m), DBH range 2' - 3'3 (0.6 - 1 m)
Colour	:	Sapwood pale brown, 1.6 in (40mm) wide and clearly defined. Hardwood pale red when freshly cut, turning orange red or red-brown with age
Grain	:	Interlocked, occasional ribbon figure on quartersawn face
Texture	:	Coarse
Working properties	:	Timber is rather abrasive which may affect planing. Sawing and machining properties good, but extractives can clog up saws. Timber turns well, and whilst it holds nails well, will require pre-boring before nailing if the timber is dry. Takes oils, water base paints and waxes satisfactorily.
Seasoning characteristics	:	Rather difficult to season, but checking can be avoided by carefully controlling drying conditions in the early stages. Small knots tend to check if wood is dried below 12% moisture content. Serious degrade can be prevented if stock is air dried to below 25% moisture content before kiln seasoning.
Shrinkage	:	7% radial, 9% tangential
Durability	:	Class 2 - 3
Strength group	:	S4 (native), S4 (plantation Hawaii) SD4-5
Characteristic defects	:	Dimensionally unstable in changing atmospheric conditions. Logs prone to sap stain and pinhole borer attack in Australia. However, better control of drying conditions may offset this. Because of drying degrade it is not favoured for building purposes. Hawaiian grown timber has produced significant brittleheart.
Termites and treatability	:	The heartwood is untreatable with preservative but moderately resistant to termites. The sapwood is resistant to treatment.
Lyctus susceptibility	:	Susceptible
Common uses	:	structural timber (heavy) flooring boat building cabinet work mouldings pulpwood joinery poles craftwood

1.15.3 Eucalyptus saligna

Species	:	*Eucalyptus saligna* (saligna or Sydney blue gum)

Family	:	Myrtaceae
General description	:	Hardwood; Density Class 9 (Australia - native) Class 8+ (Hawaii plantation); Grows 130 - 165 ft (39 - 50 m), DBH range 4' - 6'6'' ft (1.2 - 2 m)
Colour	:	Sapwood pale brown, 2'0'' (50mm) wide not always clearly defined. Heartwood pink to light red-brown, darkening on exposure.
Grain	:	Varies from interlocked to straight
Texture	:	Medium to coarse
Working properties	:	Properties and strength vary with age and density, but is generally easy to work. Straight grained timber planes to a smooth finish, with some occasional tearing out. Dimension timber and cants can spring as they come from the saw. Takes stains and glue well and bores cleanly.
Seasoning characteristics	:	Seasons easily but with the possibility of some extension of initial splitting. Inner heartwood is inclined to split quite severely. Fast grown stock may kiln dry in 10 days and air dry in 2 months, but older material requires more time. Can warp and collapse - this can be rectified with reconditioning.
Shrinkage	:	5.4% radial, 9.5% tangential BR 3.7% radial, 5.8% tangential AR
Durability	:	Class 3
Strength group	:	S3 (native) S3 (plantation Hawaii) SD3
Characteristic defects	:	Dimensionally unstable in changing atmospheric conditions. Logs prone to marine borer attack.
Termites and treatability	:	Prone to termite attack. The sapwood is moderately permeable to preservatives but the heartwood is resistant.
Lyctus susceptibility	:	Susceptible
Common uses	:	structural timber flooring boat building veneer/plywood pulpwood interior trim joinery hardboard/particleboard poles

1.15.4 Flindersia brayleyana

Species	**:**	*Flindersia brayleyana* (Queensland maple)

Family	**:**	Flindersiaceae
General description	**:**	Hardwood; Density Class 7+ (Australia - native) Class 8 (Papua New Guinea); Grows 100 - 130 ft (30 - 40 m), DBH range 3' - 6'6'' (1 - 2 m)
Colour	**:**	Sapwood narrow, greyish, heartwood varies from pinkish brown to pale brown
Grain	**:**	Often interlocked producing a wide variety of stripe and fiddleback figure
Texture	**:**	Medium and even
Working properties	**:**	Stains and polishes to a lustrous finish, peels and slices easily, glues and nails well. Very strong in proportion to its weight. Buckles in response to steam bending.
Seasoning characteristics	**:**	Moderate seasoning properties because of interlocked grain. Cupping of wide backsawn boards can occur. Seasoning in thicknesses to 70 mm is usually satisfactory although some collapse may occur.
Shrinkage	**:**	3% radial, 6.5% tangential
Durability	**:**	Class 2 - 3
Strength group	**:**	S6 (Australian native) S5 (PNG native) SD6
Characteristic defects	**:**	Not suitable for steam bending.
Termites and treatability	**:**	Very susceptible to dry wood termites (*Cryptotermes*). The sapwood is treatable with preservative but heartwood is very resistant.
Lyctus susceptibility	**:**	Not susceptible
Common uses	**:**	structural timber boat building mouldings cabinet work and furniture veneer/plywood interior trim joinery craftwood

1.15.5 Fraxinus uhdei

Species	**:**	*Fraxinus uhdei* (tropical ash)

Family	**:**	Oleaceae
General description	**:**	Hardwood; Density Class 7+ (Mexico - native) Class 7 (Hawaii plantation); Grows 80 - 100 ft (24 - 30 m), DBH range about 20'' (0.5 m)
Colour	**:**	Timber pale brown when freshly sawn, turning darker on exposure. Sapwood and heartwood look the same
Grain	**:**	Straight
Texture	**:**	Medium
Working properties	**:**	End splits may extend in drying. Planes, bores, turns and mortises with only a little woolliness and tear out. Steam bending properties and wearing characteristics good. Species finishes, stains, varnishes, polishes and glues well.
Seasoning characteristics	**:**	Timber seasons well with little degrade except at high kiln temperatures when warping may occur. End splits may extend in drying.
Shrinkage	**:**	2.1 to 4% radial, 4.1 to 7% tangential
Durability	**:**	Class 4
Strength group	**:**	S5 (Mexico & Hawaii)
Characteristic defects	**:**	Susceptible to blue stain. Pinhole borers attack living trees. Timber is susceptible to other insects.
Termites and treatability	**:**	Susceptible to termite attack. Sapwood is permeable to preservatives; heartwood is moderately resistant.
Lyctus susceptibility	**:**	Susceptible
Common uses	**:**	structural timber flooring boat building cabinet work and furniture veneer/plywood pulpwood interior trim joinery poles craftwood

1.15.6 Grevillea robusta

Species	:	*Grevillea robusta* (silver oak or southern silky oak)

Family	:	Proteaceae
General description	:	Hardwood; Density Class 7+ (Australia - native) Class 7 (Hawaii plantation); Grows to 120 ft (36 m), DBH range 1'6'' - 3' (0.5 - 1 m)
Colour	:	Heartwood pink or light red when freshly cut turning yellow-brown to red brown on drying
Grain	:	Straight or wavy
Texture	:	Medium to coarse
Working properties	:	Green timber saws well. Planes mortices and chisels satisfactorily. Moulds cleanly but a 10% cutting angle required to obtain good finish on quartersawn faces. Species liable to split when nailing. Contact with wet or dry wood, sap, sawdust or shavings can cause mild to severe dermatitis/allergic reactions.
Seasoning characteristics	:	Air seasons slowly with some tendency to distort, check and end split, particularly if the heart is boxed in and distorts near knots. However 1'' (25 mm) boards season well.
Shrinkage	:	2% radial, 5% tangential (Australia native, Hawaii plantation)
Durability	:	Class 3 - 4
Strength group	:	S5 (Australia) S6 (Hawaii) SD5
Characteristic defects	:	Liable to marine borer, pinhole borer and termite attack. Impregnation properties variable. Can be slow growing in some plantations due to its production of phytotoxins to inhibit growth of other trees of the same species (allelopathy).
Termites and treatability	:	Liable to termite attack. Treatability varies but sapwood is usually permeable to preservatives and heartwood moderately resistant.
Lyctus susceptibility	:	Susceptible
Common uses	:	structural timber flooring cabinet work and furniture pulpwood interior trim joinery hardboard/particleboard

1.15.7 Toona ciliata

Species	**:**	*Toona ciliata* (Australian red cedar or toon)

Family	**:**	Meliaceae
General description	**:**	Hardwood; Density Class 6 (Australia- native, Hawaii - plantation); Grows 100 -130 ft (30 - 42 m), DBH range 3'1'' - 6'6'' (1 - 2 m)
Colour	**:**	Heartwood cedar brown or brick red, turning darker on exposure
Grain	**:**	Straight, occasionally slightly interlocked
Texture	**:**	Medium to coarse
Working properties	**:**	Timber easy to saw and work, taking a good polish and stain. Peels and moulds well and nailing and gluing properties are good, holding power poor.
Seasoning characteristics	**:**	Dries rapidly without much distortion or checking. Collapse can occur, but the wood is easily reconditioned. Close spacing of stickers and weighting of stacks important.
Shrinkage	**:**	2% radial and 4% tang. BR, 1.5% radial and 3% tang. AR (Australia) Shrinkage could be double the above in Hawaiian grown timber since this is from plantations.
Durability	**:**	Class 2 - 3 (Australia native) Class 4 (Hawaii plantation)
Strength group	**:**	S7
Characteristic defects	**:**	Plantation material not very resistant to decay and must not be used in exposed situations. Growth stresses can cause end splitting and spring (crook).
Termites and treatability	**:**	Generally regarded as durable; however, since plantation material is not very resistant to decay, it seems likely such material will not be resistant to termites. The wood is resistant to treatment with preservatives.
Lyctus susceptibility	**:**	Susceptible
Common uses :		structural timber boat building cabinet work and furniture veneer/plywood interior trim craftwood mouldings

1.15.8 Cryptomeria japonica

Species	**:**	*Cryptomeria japonica* (sugi)

Family	**:**	Taxodiaceae
General description	**:**	Softwood; Density Class 5+ (Japan - native) Class 4 (South Africa); Established successfully in Taiwan, India, Sri Lanka and many African countries; Grows 130 - 200 ft (40 - 60 m), DBH range 3’3’’ - 10’ (1 - 3 m)
Colour	**:**	Heartwood pale yellowish, turning brown with age. Sapwood distinct, creamy white or yellow
Grain	**:**	Variable
Texture	**:**	Medium to coarse
Working properties	**:**	Timber easy to saw and work, taking a good polish and stain. Holds nails well - care required when nailing to avoid splitting.
Seasoning characteristics	**:**	Care needed in drying to avoid checks and splits
Shrinkage	**:**	2% radial, 4% tangential
Durability	**:**	Class 2 - 3
Strength group	**:**	Up to S7 SD8
Characteristic defects	**:**	Not suitable for ordinary building purposes. Frequent knots in timber. Oil content of some trees may give finishing problems.
Termites and treatability	**:**	Normally regarded as not resistant to termites. Can be treated with preservatives for termite resistance.
Lyctus susceptibility	**:**	Not susceptible
Common uses	**:**	boat building cabinet work veneer/plywood pulpwood, interior trim joinery hardboard/particleboard poles (traditional Japanese use as structural or ornamental posts) craftwood.

2. Case Study: Waiakea and Hamakua Coast State Forests

2.1 Introduction

There are State owned plantations on many of the Hawaiian Islands which have been established for a wide range of uses. Most are managed under the Division of Forestry and Wildlife (DOFAW) multiple use policy which covers protection and habitat for wildlife, slope stabilisation, soil and catchment protection, visual amenity and recreation. Some of these plantations will also be used for commercial forestry if a benefit to the State can be demonstrated. The State of Hawaii has developed forest plantations in the Waiakea and Hamakua Coast regions on the Island of Hawaii (the Big Island).

The commercial value of the Waiakea and Hamakua plantations has become an issue as the trees can now be considered mature and ready for harvesting. This case study shows the potential of these plantations to supply industry with sawlogs and pulpwood suitable for processing into value-added products on the Big Island. Care should be taken in attempting to apply this data to other areas of plantation both on the Big Island and on other islands. Many other factors need to be considered, the most important being whether or not the plantations are available for harvesting.

2.2 Location

The Waiakea and Hamakua plantations are situated on the Hamakua-Hilo coast on the Island of Hawaii on land between 1,000 and 3,000 feet asl with a mean annual rainfall of between 80 and 160 inches (2,000 and 4,000 mm); ample for growing trees (Appendix 1). Waiakea is located about 4 miles south of Hilo township; the Hamakua plantations are dispersed along the Hamakua coast from the Waimea township in the north to the Pepe'ekeo township in the east. Existing all weather roads access the majority of both plantation estates.

The standing volume data by 3 diameter classes were provided by Michael Constantinides of DOFAW (Appendix 2).

These data were given in cubic feet (ft^3), which have been retained for log volumes[1]. However, sawn timber volumes have been converted to board feet (bf) log and sawn timber volumes are also given in cubic metres (m^3).

In order to use these data, logs were classified as follows:

Type of log	Small end diameter
Pulpwood	4 to 8 inches (10 to 20 cm)
Small sawlog	8 to 12 inches (20 to 30 cm)
Sawlog	> 12 inches (>30 cm)

Any area which contained less than 1,000 ft^3/acre (70 m^3/ha) of sawlogs was regarded as non-commercial, i.e. not yet ready for harvesting. This eliminated *Grevillea robusta* entirely from consideration and there were relatively minor quantities of *Flindersia brayleyana*, *Toona ciliata*, *Fraxinus uhdei* and *Cryptomeria japonica*. The major species are *Eucalyptus robusta* and mixed *E. saligna* and *E. grandis*.

The major species of those under study in this report are *Eucalyptus robusta* and mixed *E. saligna* and *E. grandis*. However, there were other species of eucalypts on the Hamakua coast, only one of which is named in the Constantinides work (*E. globulus*) which could yield significant volumes of sawlogs. The *E. globulus*, in fact, will yield only minor quantities of sawlogs; the unnamed species are much more important in terms of volume available. If these species are suitable as sawlogs, e.g. *E. microcorys*, they could provide a significant additional resource which should be investigated in more detail. The volumes will be presented in Section 2.1.3.

1 1 m^3 = 35.315 ft^3 log volume
1 m^3 = 424 bf sawn timber volume
1 Mbf = 2.358 m^3 sawn timber volume

2.3 Waiakea Sawlog

The current standing volumes are presented in ft³ and m³, and net areas in acres and hectares, in Tables 2-1 and 2-2 respectively.

Table 2-1: Waiakea (volumes in '000s ft³)

Species	Harvestable area in acres	Pulpwood volume	Small sawlog volume	Sawlog volume	Total sawlog volume	Total volume	Av. vol. per acre	Age
F. brayleyana	529	574	778	583	1,360	1,934	3.7	29-32
E. saligna and *E. grandis*	2,908	2,959	3,896	2,176	6,072	9,031	3.1	14-31
E. robusta	227	179	262	736	998	1,177	5.2	30-59
T. ciliata	321	368	354	145	499	867	2.7	30-35
Sub-totals	**3,986**	**4,079**	**5,289**	**3,640**	**8,930**	**13,009**	**3.3**	

Table 2-2: Waiakea (volumes in m³)

Species	Harvestable area in ha	Pulpwood volume	Small sawlog volume	Sawlog volume	Total sawlog volume	Total volume	Av. vol. per ha	Age
F. brayleyana	214	16,241	22,024	16,499	38,523	54,764	256	29-32
E. saligna and *E. grandis*	1,177	83,790	110,324	61,624	171,948	255,738	217	14-31
E. robusta	92	5,070	7,409	20,841	28,250	33,320	362	30-59
T. ciliata	130	10,416	10,021	4,114	14,135	24,551	189	30-35
Sub-totals	**1,613**	**115,517**	**149,778**	**103,078**	**252,856**	**368,373**	**228**	

The total current standing volume of sawlogs in State forests of Waiakea (including small sawlogs) is about 8.9 million ft³ (253,000 m³).

Assuming the resource is harvested over 5, 10, 15 or 20 years, and using the calculated average MAI for sawlogs of 115 ft³/acre/a (8 m³/ha/a), the average annual sawlog volumes available for harvesting are indicated in Tables 2-3 and 2-4.

Table 2-3: Sawn timber estimates for Waiakea in Mbf (3,986 acres)

Growth period in years	Current sawlog vol. in '000s ft³	Sawlog MAI in ft³/acre/a	Total sawlog vol. in 000's ft³	Annual sawlog vol. in 000's ft³	Annual lumber output in Mbf *
5	8,930	115	10,069	2,014	9,666
10	8,930	115	11,208	1,121	5,380
15	8,930	115	2,347	823	3,951
20	8,930	115	13,487	674	3,237

* Assuming 40% recovery

Table 2-4: Sawn timber estimates for Waiakea in m³ (1,613 ha)

Growth period in years	Current sawlog vol. in m³	Sawlog MAI in m³/ha/a	Total sawlog vol. in m³	Annual sawlog vol. in m³	Annual lumber output in m³
5	252,856	8	285,116	57,023	22,809
10	252,856	8	317,376	31,738	12,695
15	252,856	8	349,636	23,309	9,324
20	252,856	8	381,896	19,095	7,638

The current Waiakea resource alone may not support a sawmill which is commercially viable. A normal write-off period for a hardwood mill is about 15 years. Over this period, about 0.8 million ft³ of logs (23,000 m³) would be available annually. If it's possible to combine the Waiakea and Hamakua resources, the situation would change significantly.

Hamakua sawlogs

The same format has been followed as for Waiakea. Tables 2-5 and 2-6 give the current standing volumes in ft³ and m³ and net areas in acres and hectares respectively for the species under study.

Table 2-5: Hamakua (volumes in 000's ft³)

Species	Harvestable area in acres	Pulpwood volume	Small sawlog volume	Sawlog volume	Total sawlog volume	Total volume	Av. vol. per acre	Age
E. saligna	435	622	891	2,144	3,035	3,657	8.4	20/62
E. robusta	1,895	2,072	3,323	13,039	16,362	18,434	9.7	63
T. ciliata	94	184	245	184	429	613	6.5	29
F. uhdei	274	283	261	458	718	1,001	3.6	62
C. japonica	138	304	284	203	488	792	5.7	64
Sub-totals	**2,837**	**3,465**	**5,004**	**16,028**	**21,032**	**24,497**	**8.6**	

Table 2-6: Hamakua (volumes in m³)

Species	Harvestable area in ha	Pulpwood volume	Small sawlog volume	Sawlog volume	Total sawlog volume	Total volume	Av. vol. per ha	Age
E. saligna	176	17,619	25,225	60,721	85,946	103,565	588	20/62
E. robusta	767	58,673	94,098	369,212	463,310	521,983	681	63
T. ciliata	38	5,205	6,938	5,217	12,155	17,360	457	29
F. uhdei	111	8,011	7,378	12,963	20,341	28,352	255	62
C. japonica	56	8,616	8,045	5,762	13,807	22,423	400	64
Sub-totals	**1,148**	**98,124**	**141,684**	**453,875**	**595,559**	**693,683**	**604**	

The total current standing volume of sawlogs of the species under study on Hamakua (including small sawlogs) is about 21 million ft^3 or about 596,000 m^3.

In addition to the volumes available of the species under study, there are about 6.4 million ft^3 (182,500 m^3) of unnamed species of eucalypts on the Hamakua coast which might be used as sawlogs, i.e. an increase of about 30% over the total sawlog volume given in Tables 2-5 and 2-6. The annual sawlog volumes and lumber outputs in Tables 2-7 and 2-8 should also be increased by about 30% to take the above into account.

Assuming the potential sawlog resource, excluding the unnamed species, is harvested over 5, 10, 15 or 20 years and an average MAI for sawlogs of 115 ft^3/acre/a (8 m^3/ha/a), total average annual volumes available for harvesting are indicated in Tables 2-7 and 2-8.

Table 2-7: Sawn timber estimates for Hamakua in Mbf (2,837 acres)

Growth period in years	Current sawlog vol. in '000s ft^3	Sawlog MAI in ft^3/acre/a	Total sawlog vol. in '000s ft^3	Annual sawlog vol. in '000s ft^3	Annual lumber output in Mbf
5	21,032	115	21,843	4,369	20,969
10	21,032	115	22,654	2,265	10,874
15	21,032	115	23,464	1,564	7,509
20	21,032	115	24,275	1,214	5,826

Table 2-8: Sawn timber estimates for Hamakua in m^3 (1,148 ha)

Growth period in years	Current sawlog vol. in Mbf	Sawlog MAI in m^3/ha/a	Total sawlog vol. in m^3	Annual sawlog vol. in m^3	Annual lumber output in m^3
5	595,559	8	618,519	123,704	49,482
10	595,559	8	641,479	64,148	25,659
15	595,559	8	664,439	44,296	17,718
20	595,559	8	687,399	34,370	13,748

The Hamakua sawlog resource on its own is sufficient to support a sawmill. For a normal sawmill write-off period of about 15 years, the annual volume of sawlogs available would be about 1.6 million ft^3 (44,000 m^3). This would increase to about 2 million ft^3 (57,000 m^3) if the additional volume of unnamed eucalypts is taken into account. Combined with the Waiakea resource over this period, the annual sawlog availability would thus be about 2.4 million ft^3 (67,600 m^3) or 2.8 million ft^3 (80,000 m^3) with the additional resource of unnamed eucalypts.

2.3.1 Pulpwood logs and mill residues

Both pulpwood logs and mill residues can produce woodchips. Tables 2-9 and 2-10 indicate the total combined resource at present by species (excluding the mixed species, unnamed eucalypts). The data are given in green metric tonnes (mt) and US short tons, assuming that 1 ft^3 is equivalent to 62.5 lbs, 1 m^3 is equivalent to 1 mt and that recovery of chips from sawlogs in mt is 40% of sawlog volume.

Table 2-9: Total pulpwood availability at present in US tons

WAIAKEA

Species	Pulpwood mass in tons	Total sawlog volume '000's ft³	Sawlog chips in tons	Total mass of chips in tons
F. brayleyana	17,908	1,360	16,987	34,895
E. saligna and *E. grandis*	92,389	6,072	75,822	168,212
E. robusta	5,590	998	12,457	18,047
T. ciliata	11,485	499	6,233	17,718
Sub-totals	**127,372**	**8,930**	**111,499**	**238,872**

HAMAKUA

Species	Pulpwood mass in tons	Total sawlog volume 000's³	Sawlog chips in tons	Total mass of chips in tons
E. saligna	19,422	3,035	37,899	57,321
E. robusta	64,680	16,362	204,301	268,981
T. ciliata	5,738	429	5,360	11,098
F. uhdei	8,832	718	8,970	17,802
C. japonica	9,498	488	6,088	15,586
Sub-totals	**108,170**	**2,1032**	**262,618**	**370,788**

Table 2-10: Total pulpwood availability at present in metric tonnes

WAIAKEA

Species	Pulpwood mass in mt	Total sawlog volume in m³	Sawlog chips in mt	Total mass of chips in mt
F. brayleyana	16,241	38,523	15,409	31,650
E. saligna and *E. grandis*	83,790	171,948	68,779	152,569
E. robusta	5,070	28,250	11,300	16,370
T. ciliata	10,416	14,135	5,654	16,070
Sub-totals	**115,517**	**252,856**	**101,142**	**216,659**

HAMAKUA

Species	Pulpwood mass in mt	Total sawlog volume in m³	Sawlog chips in mt	Total mass of chips in mt
E. saligna	17,619	85,946	34,378	51,997
E. robusta	58,673	463,310	185,324	243,997
T. ciliata	5,205	12,155	4,862	10,067
F. uhdei	8,011	20,341	8,136	16,147
C. japonica	8,616	13,807	5,523	14,139
Sub-totals	**98,124**	**595,559**	**238,224**	**336,348**

The total current availability of pulpwood and residues combined is about 610,000 tons or 553,000 mt.

Assuming the pulpwood resource is harvested over 5, 10, 15 and 20 years and using the calculated pulpwood MAI of 1.82 tons/acre/a (4 mt/ha/a), the average annual volumes available for harvesting and the availability of sawmill residues are given in Tables 2-11 and 2-12.

Table 2-11: Annual pulpwood estimates (in tons)

WAIAKEA

Growth period in years	Annual sawlog vol. in 000's ft³	Annual sawmill residues in tons	Annual pulpwood in tons	Total pulpwood and residues in tons
5	2,014	25,160	29,102	54,262
10	1,121	14,010	16,365	30,375
15	823	10,294	12,119	22,412
20	674	8,435	9,996	18,431

HAMAKUA

Growth period in years	Annual sawlog vol. in 000's ft³	Annual sawmill residues in tons	Annual pulpwood in tons	Total pulpwood and residues in tons
5	4,369	54,559	25,261	79,821
10	2,265	28,298	14,444	42,742
15	1,564	19,544	10,839	30,382
20	1,214	15,167	9,036	24,202

WAIAKEA AND HAMAKUA

Growth period in years	Annual sawlog vol. in Mbf	Annual sawmill residues in tons	Annual pulpwood in tons	Total pulpwood and residues in tons
5	6,383	79,719	54,363	134,083
10	3,386	42,308	30,809	73,117
15	2,387	29,838	22,958	52,795
20	1,888	23,602	19,032	42,634

Table 2-12: Annual pulpwood estimates (in mt)

WAIAKEA

Growth period in years	Annual sawlog vol. in m³	Annual sawmill residues in mt	Annual pulpwood in mt	Total pulpwood and residues in mt
5	57,023	22,809	26,329	49,139
10	31,738	12,695	14,778	27,473
15	23,309	9,324	10,927	20,251
20	19,095	7,638	9,002	16,640

HAMAKUA

Growth period in years	Annual sawlog vol. in m³	Annual sawmill residues in mt	Annual pulpwood in mt	Total pulpwood and residues in mt
5	123,704	49,482	22,851	72,332
10	64,148	25,659	13,038	38,698
15	44,296	17,718	9,768	27,486
20	34,370	13,748	8,132	21,880

WAIAKEA AND HAMAKUA

Growth period in years	Annual sawlog vol. in m³	Annual sawmill residues in mt	Annual pulpwood in mt	Total pulpwood and residues in mt
5	180,727	72,291	49,180	121,471
10	95,886	38,354	27,816	66,170
15	67,605	27,042	20,695	47,737
20	53,465	21,386	17,134	38,520

For a growth period of 15 years, the annual quantity of pulpwood and residues combined is about 53,000 tons or 48,000 mt; too small for industrial paper operations in Hawaii unless the supply can be greatly augmented from other sources. It should be noted that some volumes of pulpwood may be available from the "non-commercial" areas of low standing volume. The additional quantity available from the unnamed eucalypt species (Section 2.1.3) would be relatively small.

2.3.2 Conclusions regarding the Waiakea and Hamakua plantations

If harvesting of the existing known resource was to start now and continue for 15 years, there would be enough small sawlogs and sawlogs combined to justify a substantial sawmill, provided both Waiakea and Hamakua can be logged and the logs delivered to one mill. Alternatively, two green sawmills could be established which supply lumber to a centralised drying and value-adding operation. However, the quantities of pulpwood and residues combined would be insufficient to justify their industrial use unless supply can be greatly augmented from other sources. Opportunities for the pulp logs and residues could be:

- combined with a woodchip export operation based on private plantations
- fuel to run boilers and kilns
- as biofuels to produce electricity

Table 2-13 gives some information gleaned from the Government of Hawaii website. (www.Hawaii.gov:8080/databook/db1995a/2000/.95). However, as discussed in Section 2.1.1, it should not be assumed that all these areas are intended or available for harvest.

Table 2-13: Planted forests in Hawaii up to 1995

	AREA	
Island	**acres**	**ha**
Hawaii	17,138	6,936
Maui	11,892	4,812
Lanai	512	207
Molokai	3,238	1,310
Oahu	7,162	2,898
Kauai	6,249	2,529

According to the inventory data provided for this study by Michael Constantinides, there are 11,125 acres (4,502 ha) of State owned forest at Waiakea (including currently non-merchantable stands) and 2,878 acres (1,165 ha) of the same at Hamakua, giving a total of 14,003 acres (5,667 ha). By subtraction, the area of private plantation is about 3,135 acres (1,269 ha). An additional 15,000 acres (6,000 ha) of mainly *E. grandis* have been established on the Hamakua coast[2] by Forest Solutions in the last 3 years so that the planted forest area has virtually doubled since 1995. This suggests about 18,135 acres (7,340 ha) in private ownership; a significant additional resource which could be useful in augmenting sawmill supplies and could make a significant difference to the pulpwood situation in the medium to long term.

The area estimate for private planted forests could be subject to significant error since they are derived from several sources.

[2] On land owned by Kamehameha Schools/Bishop Estate, leased by Prudential Timber Investments Inc. and managed for PruTimber by Forest Solutions.

We would recommend, therefore that a sufficiently detailed inventory should be carried out to determine merchantable quantities available and to make growth predictions for the next 20 years, at least on the Island of Hawaii.

2.4 Quantity Estimates for each Species

It is not possible to make quantity estimates for each of the species outside those provided in Section 2 for the Waiakea and Hamakua Coast State Forests. DOFAW was not prepared to provide data on other areas of planted forests because of their concern that the provision of this data may imply that these areas are available for harvesting and ongoing commercial forestry. It is most likely that commercial forestry in the Waiakea and Hamakua Coast State Forests will act as a guide to the likelihood of harvesting in other areas.

There are substantial areas of these species in privately owned plantations, some of which are mature and available for harvesting. No major landowners have completed resources inventories and the private resource data from interviews and questionnaire surveys during this study were insufficient for reliable analysis.

It is possible that this area could significantly augment the state-owned resource if combined. The importance of operational scale and international competitiveness is detailed later in this report. It may be that a processing industry would only be viable if both the private and public resource were available. This highlights the need for good quality resource data to attract investment in forest industries.

Some of the highest growth rates for plantations anywhere in the world can be achieved in Hawaii. Other areas in the moist tropics where comparably high growth rates might be achieved include Brazil, the Philippines, Sabah, the Congo and Papua New Guinea. Nonetheless, Hawaii has a competitive advantage which has been recognised by a number of investors who are establishing plantations on ex-sugar cane land. These plantations can complement the existing plantations, both private and state, by ensuring wood supply to processing industries during the replanting phase. A longer term goal should be to develop a relatively even age class distribution across all plantations to allow a sustainable reliable supply for industry.

2.5 Future Possibilities

From the perspective of a world scale project in Hawaii, the detailed information presented on the Waiakea and Hamakua plantations is not yet encouraging. However, the State of Hawaii has an ideal climate for growing planted forests quickly so that future possibilities are worth exploring.

2.5.1 Available Land

A land base of sufficient area would be required for a world scale project and it will be important to continue discussions with the following landowners:

- State of Hawaii
  - Department of Hawaiian Home Lands (DHHL)
  - Department of Land and Natural Resources (DLNR)
- C. Brewer and Co.
- KSBE (Bishop Estate)
- Parker Ranch
- County of Hawaii
- Strother Timberlands.

Island of Hawaii

Securing sufficient land to create economies of scale will be very important. A brief review of the potential land on the island of Hawaii suggests that over 74,000 acres (30,000 hectares) could be available in the near future with more options if the project develops landowner appeal.

The islands do not, as yet, have any real understanding of hardwood plantations; some education and some cultural changes will be required. It will be imperative that sufficient land is planted to give economies of scale. An estate of 74,000 acres (30,000 hectares) is considered as a minimum to achieve plantation and processing economies of scale and to justify infrastructure investment. Assuming intensive management, an average MAI of 500 ft^3/acre/a (35 m^3/ha/a) could be achieved so that this estate would yield over 37,000,000 ft^3/a or 1,050,000 m^3/a which is more than sufficient to supply a range of world scale processing plants except for a chemical pulp mill. However, these estimates must be tempered by the reality of what has been achieved so far. The data provided by Michael Constantinides, the only detailed up-to-date data we have, indicates a weighted average MAI on Waiakea of only 77 ft^3/acre/a (5.4 m^3/ha/a) over an average age of 31; on Hamakua of 156 ft^3/acre/a (10.9 m^3/ha/a) over an average age of 59.

While further work is required on land availability, Table 2-14 indicates possible areas available on the Big Island. The figures are uncertain because of varying opinions on where plantations will grow. For instance, some landowners feel plantations will not grow in less than 50 inches of annual rainfall.

Table 2-14: Available land area (acres) for afforestation on the Island of Hawaii

Landowner	Upper Elevations	Hamakua Coast	Hilo Coast	Waiakea	Ka'u	Kona Kohala etc
KSBE		13,500	2,300		6,000	25-30,000
C. Brewer			10,000		20,000	
State of Hawaii	15,000	6,500		12,000	5,000	
Parker Ranch	15,000					
Hawaii County		4,000				
Total	30,000	24,000	12,300	12,000	31,000	25-30,000
Potential for Plantations	25,000	21,000	6,300	12,000	16,000	10,000
					TOTAL	**90,300**

NB: This table should be used only as a guide to indicate possible locations for plantations.

Kauai

In 1979, Kauai had about 46,000 acres (18,600 ha) of sugar land, much of which was irrigated. Many of these former sugar lands have been converted to diversified agriculture including the largest coffee estate in the United States, extensive production of seeds and other tropical crops. The State of Hawaii owns 16,000 acres (6,500 ha) which has potential for growing trees.

It also has two deep water ports at Nawiliwili (in Lihue) and Port Allen on the southern coast adjacent to the remaining sugar lands and the large coffee estate.

Two tree farm developments on private land, which will total more than 1,000 acres (400 ha) when completed, will use mainly longer rotation hardwood species than those being planted on the Island of Hawaii. In addition, two major private landowners are reviewing proposals that could lead to tree farms totalling 7,000-9,000 acres (2,800 to 3,600 ha) in the immediate future.

In general, Kauai has opportunities for at least 25,000 acres (10,000 ha) of plantations.

Oahu

On Oahu, KSBE has 5,000 to 7,400 acres (2,000 to 3,000 ha). The State also owns significant land and there is increasing government interest in sewerage effluent re-use on agriculturally zoned lands. A majority of formerly irrigated sugar lands has been converted to leased, diversified crops including coffee, truck crops, silage, seed crops, flowers etc.

In theory, Oahu could have opportunities for plantations on about 20,000 acres (8,000 ha) but because it is much more urbanised than other islands, this may be optimistic.

Kamehameha Schools Bishop Estate (KSBE)

KSBE owns about 30,000 acres (12,000 ha) along the Hamakua Coast, about 8,700 acres at Ka'u and additional large forested areas near Kona and adjoining the Volcano National Park. The majority of the Hamakua and Ka'u lands suitable for tree farms has been leased to Prudential Timber Investments Inc. (PruTimber) of Boston, Massachusetts. KSBE is reviewing its management options for their forested areas. KSBE as the largest private landowner in Hawaii, is influential in determining land use activities and policies in the State.

While KSBE have leased most of their former sugar land, both lessor and lessee have a commitment to domestic processing if such operations are economically viable.

State of Hawaii

The State of Hawaii is also a critical ally as it offers immediate log volumes from their DHHL and DLNR timber management areas and planting trials. It also has significant land holdings, managed by DHHL and DLNR, albeit somewhat scattered on all islands throughout the State.

If the growth of the 13 year old *E. grandis* plantations at Waiakea is any indication of potential productivity then the State has much to offer.

A strategic alliance with the State is obvious for both land and political reasons. It is very keen on the possibility of a major processing facility and while it does not have the prime land holding of the Bishop Estate on the Hamakua Coast, its landholdings are still very productive. It must also be remembered that from a broader perspective the State also has large holdings on the island of Kauai around Lihue (potentially up to 16,000 acres) and on Oahu.

C. Brewer

The forestry potential of C. Brewer lands along the Hilo and Hamakua coast has been affected by some recent decisions to lease land to diversified agriculture and grazing. This has been a holding decision while the company decides what their ultimate future will be. Hence, if other tree plantations progress satisfactorily and the potential domestic processing occurs, these factors could well bring about a favourable decision for further C. Brewer plantings.

Currently C. Brewer has extensive land at Ka'u which is immediately available and this would be important in establishing a viable resource on the Big Island.

As far as we understand, C. Brewer has not accepted any major tree planting proposals at present for their Ka'u or Hilo coast lands.

Strother Timberlands

In 1998, Strother Timberlands, based in Troy, Alabama, purchased 3 parcels of land in the Mountain View area of the Island of Hawaii totalling about 4,800 acres (1,940 ha). Local news reports indicate that this brings their total holdings in the Puna area to nearly 8,000 acres (3,200 ha). The same reports say that current plans include subdividing and selling portions of their land to recoup some of the cost of the land purchases prior to tree farm development. While their primary business in southeastern USA is pine plantation ownership, the dominant species for their Puna developments is undecided.

Parker Ranch

Parker Ranch has been approached by representatives of forest product companies with proposals to lease portions of their grazing land which may be suitable for forestry plantings. Involvement in forestry by Parker Ranch could increase the commercial forestry area by several thousand acres immediately.

County of Hawaii

The County of Hawaii has about 4,500 acres (1,800 ha) of former sugar land on the Hamakua Coast, much of it contiguous to KSBE lands being leased to PruTimber. The current County administration favourably received proposals from forest products companies to lease this land. However, activists have delayed these plans and other options are being considered by the County Council. The disposition of these public lands is uncertain at this time and may remain that way for the immediate future.

3. Practical Value-adding Processing Alternatives

A list of products best suited to the eight Hawaiian grown timbers under review has been drawn up. This takes into account differences between Hawaiian growing, harvesting, haulage, processing and marketing conditions and those elsewhere in the world where the same timber species are grown. In addition, we have considered the circumstances within Hawaii, in particular the potential volumes available and the industry and industry infrastructure to support a processing industry.

Table 3-1: Possible uses for each Hawaiian grown timber species

	SPECIES							
	E. saligna	***E. grandis***	***E. robusta***	***T. ciliata***	***C. japonica***	***F. brayleyana***	***G. robusta***	***F. uhdei***
Treated posts and poles	☯	☯			☯			
Structural sawnwood	☯	☯	☯		☯ [1]	☯	☯	☯
Flooring	☯	☯	☯		☯		☯	☯
Moulding and trim	☯	☯		☯	☯	☯	☯	☯
Furniture, cabinet work	☯	☯	☯ [2]	☯	☯	☯	☯	☯
Ship and boat building	☯	☯	☯	☯	☯	☯	☯ [3]	☯
Craftwood (carving, turnery)				☯	☯	☯	☯	☯
Veneer, plywood	☯	☯	☯	☯	☯	☯	☯	☯
Hardboard, particleboard, MDF	☯	☯			☯			☯
Paper and paperboard	☯	☯	☯		☯		☯	☯

NB: Mouldings and trims include interior and exterior mouldings.

[1] May be used only when loaded vertically on end.

[2] May be used as a face veneer in furniture.

[3] May be used for interiors.

Other hardwood species have been successfully established in plantations, particularly on the Big Island. Some of these species could make a significant contribution to the total volume available to a new processing industry (or industries). There have also been some trial plantings established on the Big Island and Kauai which will provide valuable information to help determine the most suitable species for replanting.

4.
Three Possible Market Products for each Species

All of the studied species have been used in a wide variety of applications in Hawaii, Australia and around the world. The following is a guide to the most appropriate uses.

Flindersia brayleyana

CURRENT USES:

- Framing (protected), internal flooring (covered), lining and panelling (protected), structural and non structural mouldings and joinery (Queensland Forest Service, QFS, 1991).
- The timber is an excellent cabinet wood. Tests of the Hawaiian grown species show that the timber quality is similar to that produced in Australia (Little and Skolmen, 1989).
- Furniture, decorative veneer, rifle stocks, panelling and joinery work (Bootle, 1983).

HISTORICAL REFERENCES:

- Panelling, furniture and cabinet work, (Smith, 1960).
- Boat building, chairs, furniture, panelling, turnery and sliced veneer (CSIRO, 1947).

RECOMMENDATIONS:

- Decorative veneer
- Panelling/mouldings
- Furniture/joinery

Grevillea robusta

CURRENT USES:

- Framing and boards (interior and exterior), cladding, flooring (internal and external), structural joinery, non structural joinery and mouldings (QFS, 1991).
- Face veneer, furniture, cabinet making, panelling and interiors (Little and Skolmen, 1989).
- Plywood, furniture and joinery (Bootle, 1983).

HISTORICAL USES:

- One of the best woods in all round machinability ever tested by the US Forest Products Laboratory. Used in exposed parts of furniture, upholstery frames and pallets. Excellent face veneer. Should be well suited to pulp and fibre products (Skolmen, 1974).
- Panelling and furniture (Smith, 1960).
- Bent work, brushware, carving, coffins, fence posts, furniture, linings, mouldings, panelling, building, sliced veneer (CSIRO, 1947).

RECOMMENDATIONS:

- Furniture and joinery
- Mouldings
- Decorative veneer

Toona ciliata

CURRENT USES:

- Protected and exposed boards, cladding, joinery and mouldings (QFS, 1991).
- Red cedar has not been well utilised in Hawaii. Elsewhere the timber has been used for furniture, cabinet work and construction (Little and Skolmen, 1989).
- Furniture, panelling, decorative veneer, boat building and carving (Bootle, 1983).

HISTORICAL USES:

- Timber is suitable for furniture and cabinet uses. It does not appear suitable for applications requiring high strength or hardness, but may be suitable for some types of construction, such as siding. It has been used in kitchen panelling and cabinets, but timber is too soft to be used on facing panels (Skolmen, 1974).
- Racing boats, panelling, ornamental furniture, joinery, and ornamental boxes (CSIRO, 1947).
- Window sashes, fixtures and fittings, furniture and cabinet work, cigar boxes, instrument cases, novelties, plywood and veneer, boat building (racing skiffs) (Swain, 1928).

RECOMMENDATIONS:

- Furniture
- Panelling/mouldings
- Decorative veneer

Fraxinus uhdei

CURRENT USES:

- *Fraxinus* has been used in Hawaii for furniture and panelling. Tests have shown the species to be good for veneer production (Little and Skolmen, 1989).

HISTORICAL USES:

- Furniture, cabinet work, general millwork and decorative panelling, except where high strength is required (Smith,1960).
- Primarily a furniture and cabinet wood but has been used for panelling and moulding. It lacks sufficient figure to be outstanding as a face veneer (Young, 1960).

RECOMMENDATIONS:

- Furniture
- Flooring/mouldings
- Structural plywood

Eucalyptus robusta

CURRENT USES:

- Framing and boards (exposed and interior), cladding, fascias and internal flooring (QFS, 1991).
- The wood has been used for many purposes including framing, siding and flooring in houses. It has been used in furniture, mostly for upholstered frames. It has performed well as boat framing and as conveyor slats in sugar mills. It has been used extensively in pallets and irrigation canal stakes. It has also been chipped and exported to Japan for kraft pulp manufacture (Little and Skolmen, 1989).

HISTORICAL USES:

- Boat frames, exterior construction such as picnic tables, fencing and stakes used in irrigating sugarcane (Skolmen, 1974)
- Best suited for applications where high strength is necessary. Excellent for face veneers (Smith, 1960).
- *E. robusta* could be satisfactory for fencing - but is not suitable for building purposes (Bootle, 1983).

RECOMMENDATIONS:

- Flooring
- Structural plywood (including LVL)
- Face veneers

Eucalyptus saligna

CURRENT USES:

- Framing and boards (exposed and protected), internal and external flooring (QFS, 1991).
- Used mostly for flooring and pallets. It has also been chipped and sent as pulpwood to Japan and is also the main species in biomass fuelwood plantations in Hawaii (Little and Skolmen, 1989).
- Timber decking (industrial and marine) (NAFI, 1989).
- Cladding, flooring, panelling and boat building; also has potential as a heavy furniture timber and for structural plywood (Bootle, 1983).

HISTORICAL USES:

- Suitable for picnic tables, fence posts and stakes (Skolmen, 1974).
- Cable drums, ladder rungs (CSIRO, 1947).

RECOMMENDATIONS:

- Flooring
- Plywood (older material may be suitable for face veneers)
- Structural sawnwood
- Treated Poles

Eucalyptus grandis

CURRENT USES:

- Framing and boards (exposed and internal), lining, panelling, joinery and mouldings, structural joinery (QFS, 1991).
- The species has not been used in Hawaii. Elsewhere the species has been used for poles, construction and pulpwood (Little and Skolmen, 1989).
- Panelling, joinery, furniture, general construction (Bootle, 1983).

RECOMMENDATIONS:

- Flooring
- Plywood (older material may be suitable for face veneers)
- Structural sawnwood
- Treated Poles

Cryptomeria japonica

CURRENT USES:

- One of the most important timbers of Japan; it is used for light construction, panelling, furniture and box making. To date, the main use in Hawaii has been for fence posts (Little and Skolmen, 1989).
- Decorative woodware and panelling (Bootle, 1983).
- Craft boxes.

RECOMMENDATIONS:

- Panelling
- Poles/fencing
- Light construction

5. Demand for each Market Product in Hawaii

Demand within the State of Hawaii for the products identified in Section 4 is very difficult to quantify. We attempted through interviews and surveys to obtain these data but the results were insufficient to support rigorous analysis. There are no measures of production, imports or exports (to other countries and mainland USA) and therefore there is no measure of consumption. To support investment in processing industries, it is important that these figures are collected in the future. Some information on imports of sawn softwood timber and structural plywood were obtained and this is shown in Table 5-1. As there is no known domestic production of sawn softwood or structural plywood, it can be assumed that imports equal consumption.

Table 5-1: Imports of sawn softwood and structural plywood

	Sawn softwood imports		Structural plywood	
Year	m^3	MMbf	m^3	MMbf
1993/94	97,500	41.4	69,900	29.6
1994/95	56,700	24.0	60,500	25.6
1995/96	89,100	37.8	56,800	24.1
1996/97	91,700	38.9	56,500	24.0
1997/98	103,700	44.0	53,700	22.8

Our research indicates that these two products make up a large proportion of the total forest products trade in Hawaii excluding paper. (The scale required for pulp and paper manufacture is such that a domestic Hawaiian industry is extremely unlikely to be developed, see Table 8-1). The imports of sawn softwood and structural plywood are used primarily in domestic construction, although some softwood lumber is used for fit outs such as window frames.

Resistance to termite attack is of great importance to the residential builders and at least one major builder is using steel framing to overcome termite problems. There are no treatment facilities in the state which can treat for products which may be in contact with the ground and thus most of the imported softwood lumber and some of the plywood is treated prior to shipping. There are, however, facilities for treating wood not in contact with the ground against termites. Of the imported sawn softwood, the majority is Douglas fir from the North West United States and Canada. This product is well known to the Hawaiian building industry; it is easily worked, dimensionally stable, is available in consistent quality and quantities and at a relatively stable price. These facts will make it difficult for a locally produced product to compete with Douglas fir in many applications unless there is a substantial price differential and resistance to termites can be assured.

The structural plywood market offers more opportunities for the species suitable for peeling. Termite resistance is still important in many applications but as penetration of veneers with treatment chemicals is easier than solid timber, a number of the species can be successfully treated.

Although there is some domestic demand for OSB, particleboard, MDF and hardboard, the scale required to produce these products efficiently will greatly exceed the domestic demand and, in some cases, the ability of the total forest resource to supply the fibre required. Export markets are an option; however, the Asia-Pacific region has excess capacity in OSB, MDF and particleboard and the markets for hardboard are shrinking.

Demand in Hawaii for sawn hardwood is, as with the other products, unknown. There is some local production by relatively small processors, and although the exact quantities are unknown, we estimate this is less than 5000 m^3 (212,000 ft^3) per year. Imports do occur for such things as flooring and furniture components but, again, these are unlikely to represent significant volumes. Substitution of hardwood for softwood is possible for the non-structural and appearance applications such as trim, moulding, window and door components.

The annual per capita consumption of wood and wood panels combined in the USA as a whole is about 0.63m^3 (267 bf) and in Australia about 0.3 m^3 (127 bf). Data from limited sources suggested that for Hawaii it is only 0.14 m^3 (59 bf) for 1997/98 for softwood lumber and plywood. However, it seems likely, based on lifestyle comparisons with Australia and mainland USA that the total per capita consumption of wood products would be higher than this figure. Total consumption of all solid wood products in Hawaii is estimated at between 0.2 and 0.25 m^3 (85 - 106 bf) per capita per annum.

In summary, although detailed demand figures are unavailable, the domestic markets will be unable to absorb all the production from any significant development of the industry. Export markets need to be investigated for potential products from the eight species investigated. Importantly, if the Hawaiian industry can identify export markets which can be serviced with quality, quantity and price, the industry will also be able to compete successfully with current and potential imports into Hawaii.

6. Potential Export Demand

6.1 Factors influencing the demand for and supply of wood and wood products

6.1.1 Demand

Population growth

Population growth and consumption of wood and paper products are closely linked.

Asia will be responsible for the majority of the 1.5 billion additional people in the world during the next 15 years. The total global population at that time will be about 7 billion. Currently, 60% of the Asian population is under 25 years of age and this age class represents the key emerging market.

Urbanisation

Urban people use more industrial wood per capita than rural people. It is predicted that by 2001, more people will live in towns and cities than in the countryside. Over the last three decades, the urban populations of developing countries have trebled to 1.3 billion. Asian cities are currently gaining 50 million inhabitants per year.

Improved living standards

Historically an improved standard of living is invariably accompanied by an increasing demand for wood and paper products. Most importantly increased literacy, following on from improved living standards, increases paper consumption.

6.1.2 Supply

The major general factors influencing supply are as follows:

- Far east Russia has a large resource base but low availability to the market because of poor infrastructure and political difficulties. Production has dropped to about half of what it was in the 1970's.

- Increasing domestic demand and falling harvests will combine to reduce exports from Indonesia & Malaysia. This is particularly so with Indonesia which has it's own large domestic market supply. Malaysia, with a much smaller population, will continue to be an important exporter of hardwood products. However, it's export trade in sawn hardwood will drop by about a third in the next ten years.
- The level of Japanese log imports affects domestic supplies of residue. A fall in log imports into Japan causes a corresponding fall in residues and higher demand for imported woodchips and pulp and paper products.
- The Pacific North West of the United States and Canada will drastically reduce harvests for environmental reasons, thus reducing export capacity from these regions.
- New sources of supply in Chile and New Zealand have the potential for increased net exports, but will not make up supply losses from elsewhere.
- Australia and the US South will continue to dominate export chip supplies. South Africa will gradually fade from this market as domestic consumption increases.
- China will continue to generate foreign currency with chip exports despite domestic demand for this material.
- While supply will always equal demand, the apparent wood supply deficit in the Asia-Pacific region will increase to between 1.4 billion and 2.1 billion ft^3 (40 and 60 million m^3) by 2005-2010. The potential for rising prices due to the shortfall will be wholly dependent on the level of potential substitution (JPC in-house data).

6.2 Mechanical Wood Products

Mechanical wood products include rough sawn green and dry timber as well as further processed products such as mouldings and timber components. Hardwood mechanical wood products markets are analysed and presented in the following section.

6.2.1 Global sawn hardwood

Globally, sawn hardwood is an important product both for structural and appearance type applications. Major end user groups are:

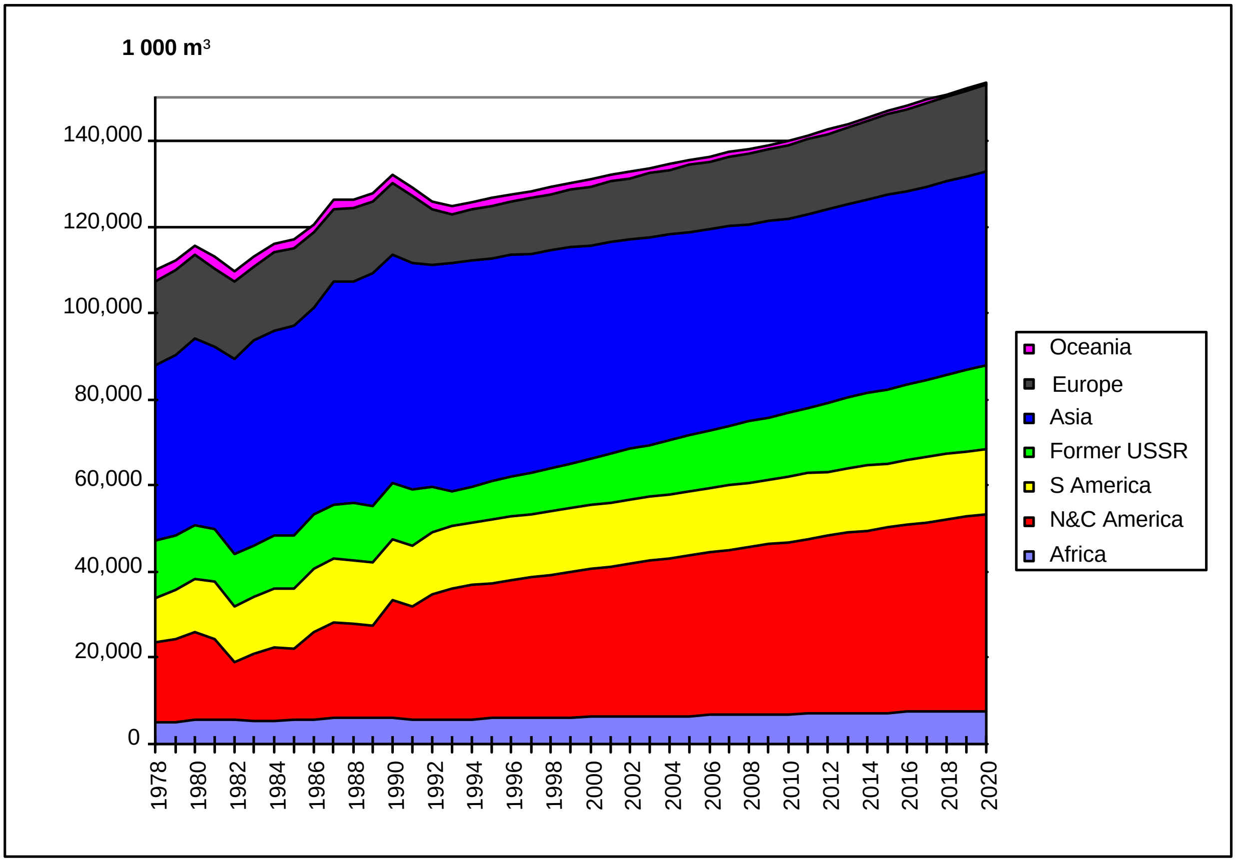
Furniture	29%
Mouldings	20%
Housing (structural)	18%
Flooring/Panelling	8%
Decorative	4%

Some general trends regarding competition and its effects on hardwood consumption are as follows:

- The use of reconstituted panels such as MDF in furniture manufacture.
- As tropical timbers become harder to procure, plantation species and other sustainably managed forest products (certified/green labelled) are being used.
- Rubberwood from Malaysia and Thailand has shown significant increases in market share. This is expected to continue as mature rubberwood plantations are harvested after they cease producing viable quantities of rubber.
- With changes in supply, including log export bans, buyers in Asia are keen to secure long-term availability. This is to ensure they have sufficient to build and consolidate market share and gain confidence with clients for supply of end products.
- Japan is a leading hardwood consumer after China and Indonesia, particularly for the wooden house market (both structural and decorative timber).
- In Korea, western style kitchens and furniture are becoming popular, thus increasing the use of wood and panel products.

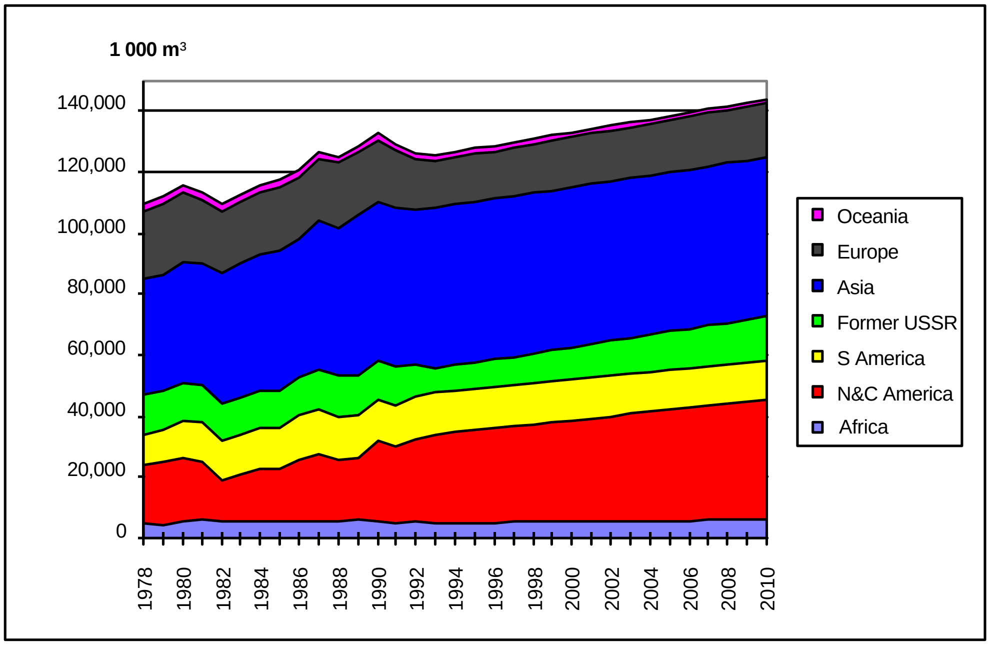
The production of sawn hardwood has traditionally been influenced by the availability of local resources. Presently the largest production of sawn hardwood is in Asia, utilising tropical hardwood resources. The second largest production area is North America utilising the temperate hardwood resource (Figure 6-1).

Figure 6-1: **Global sawn hardwood production, 1978-2010**



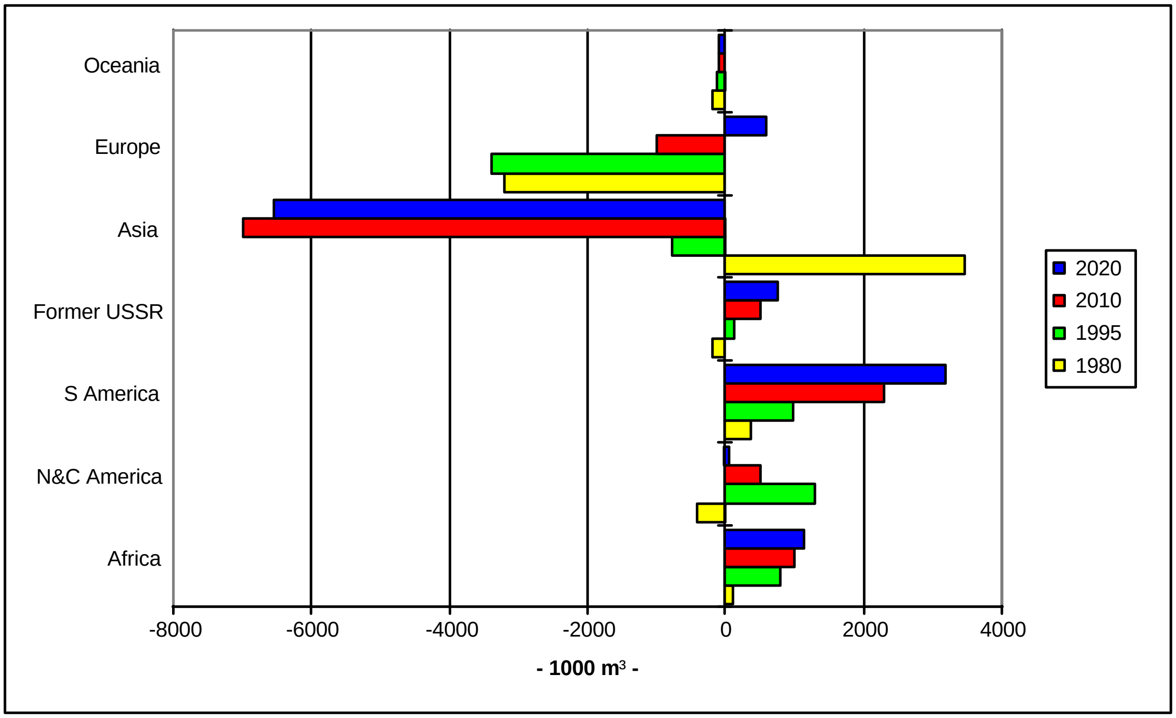
Global production of sawn hardwood increased from about 47 billion board feet (110 million m³) in 1980 to about 55 billion board feet (130 million m³) in 1991. Since then production has declined slightly, the main decline occurring in the former USSR and Europe. In the long term, production in the former USSR countries, mainly Russia, will increase. Production in North and Central America can increase immediately since the North American hardwood resource is under-utilised and the standing commercial volume is increasing. Production of sawn hardwood in Asia is expected to fall, due to the declining availability of tropical hardwood logs. The trend is expected to continue for the period 2010 to 2020.

Figure 6-2: **Global sawn hardwood consumption 1978-2010**



Sawn hardwood consumption has followed a similar trend to sawn hardwood production (Figure 6-2), Asia being by far the most important consumer. Sawn hardwood is utilised for a wide range of applications from structural materials for house construction and concrete form work to furniture, flooring, mouldings and decorative uses.

Figure 6-3: **Global sawn hardwood net trade**



Net trade developments in the different regions illustrate the changes in the ability of regional industries to maintain supplies to regional markets (Figure 6-3).

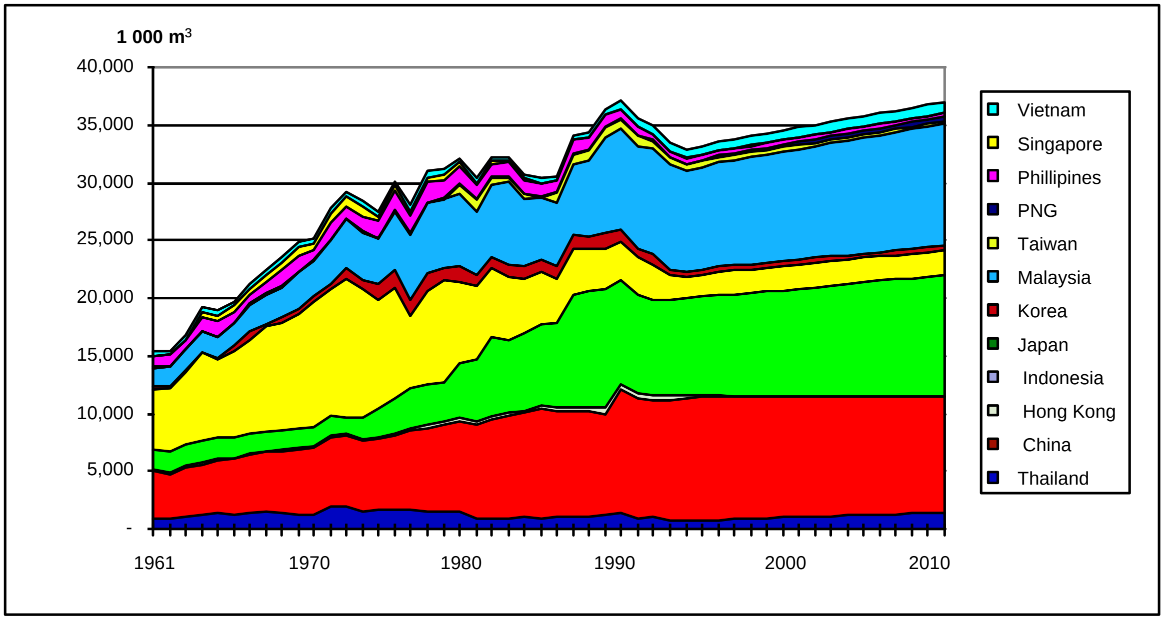
Europe, traditionally a large importer of sawn hardwood, is expected to become increasingly self sufficient, partly through increased post-war plantings coming into sawlog production and partly because of the age class structure created by large wartime fellings and subsequent regeneration. Asia's exports have declined significantly over recent years and the region is expected to become a major net importer. South America and Africa are expected to increase exports, although total available volumes are expected to remain limited.

North and Central America represent the second largest hardwood market in the world. This region is currently a net exporter however, there are some imports, particularly into the mainland USA. This market is however, extremely competitive and has a good ongoing supply of high quality hardwoods. Although freight rates from Hawaii to the mainland should be very competitive due to backloading, it may be difficult for Hawaiian products to break into this mature market. The ability to work with, rather than compete with, North American producers makes the opportunities in the emerging Asian markets more attractive to products from Hawaii. Markets in the mainland USA will probably be confined to specialist or niche products. Some Australian hardwood producers are currently supplying timber from similar species into mainland USA.

6.2.2 Asia-Pacific sawn hardwood

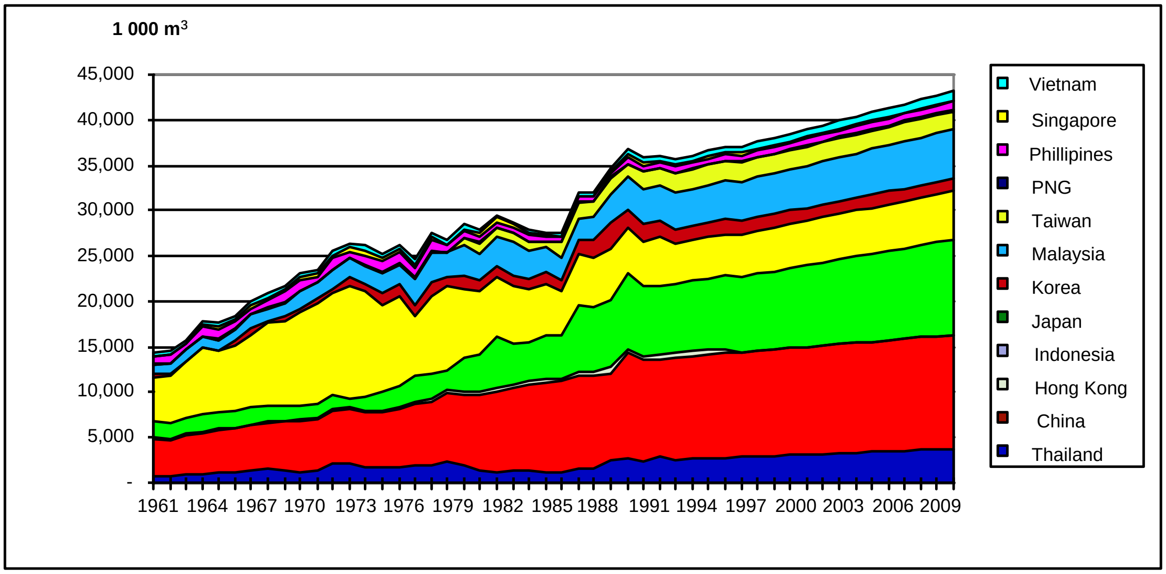
Sawn hardwood production and development in the Asia-Pacific region has increased rapidly over the past decades (Figure 6-4). Population and wealth have been increasing, resulting in rapidly increasing demand for sawn hardwood.

Figure 6-4: Asia-Pacific sawn hardwood production



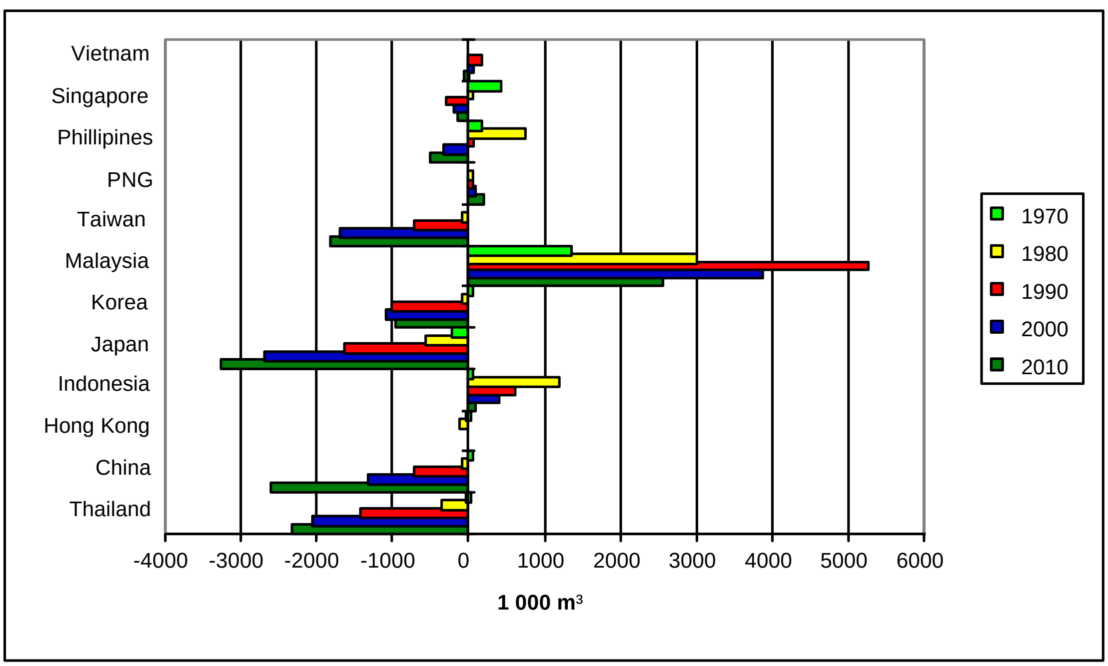
Sawn hardwood production developed rapidly in Japan until the late 1970's, principally on the basis of imported tropical hardwood logs. However, the declining availability of tropical logs has resulted in a marked decrease in Japanese sawn hardwood production during the 1980's and 1990's. Production of sawn hardwood in China, where both domestic and imported logs are used, has developed more slowly. Sawn hardwood production in Indonesia and Malaysia developed rapidly during the 1980's as log export bans forced domestic processing of logs.

Figure 6-5: **Asia-Pacific sawn hardwood consumption**



Consumption of sawn hardwood has continued to increase in the Asia-Pacific region (Figure 6-5). The major consumers are China, Indonesia and Japan although actual consumption of sawn hardwood in Japan has declined due to substitution by sawn softwood in many construction uses.

Figure 6-6: **Asia-Pacific sawn hardwood net trade**



The developments in net-trade in sawn hardwood in the Asia-Pacific region shows a decline in exports for all present exporters, and an increase in net imports (Figure 6-6). Japan will remain the largest net importer, followed by Thailand and Taiwan until 2010 when China is expected to be the second largest net importer.

6.3 Global Markets for Value-added Hardwood Products

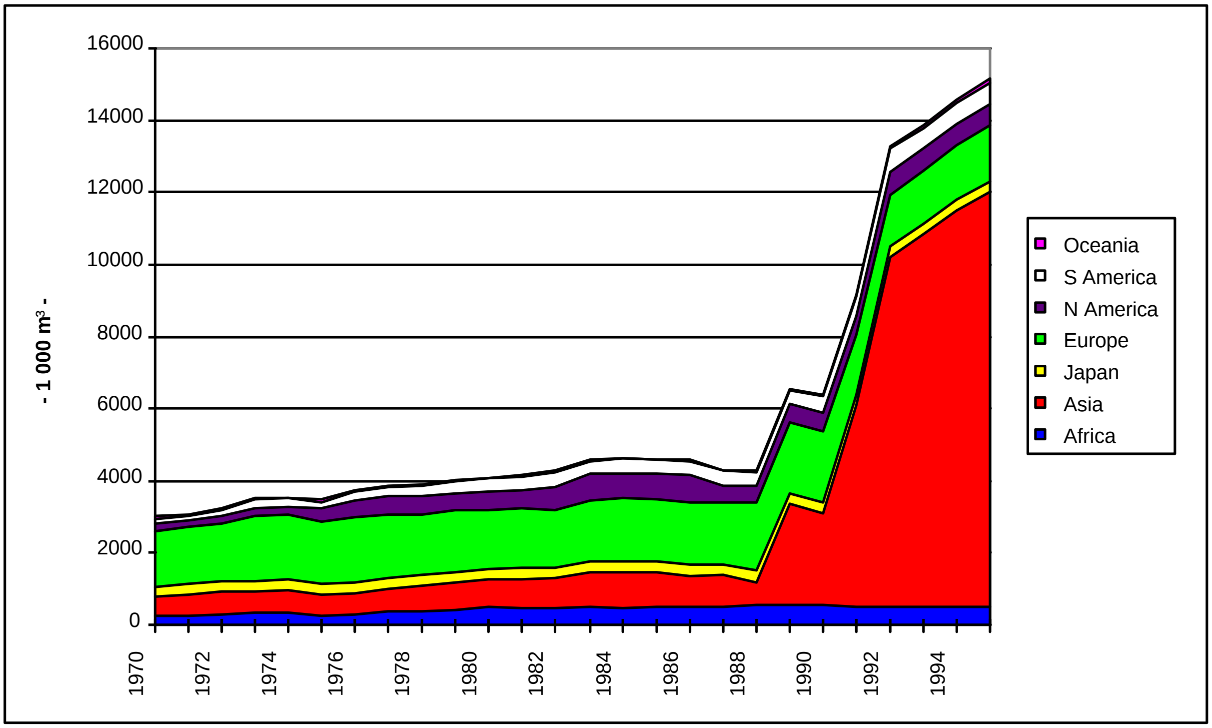
Value-added hardwood products were among the first products traded globally. The availability of desirable species and adequate skill levels in certain regions, combined with a willing market, has been the main reason for the development of trade in these products including:

- veneer
- furniture components
- mouldings
- flooring and panelling
- others, such as edge-glued panels.

6.3.1 Veneer

The international market for traded veneer has grown rapidly since 1988 as shown in Figure 6-7.

Figure 6-7: **Global production of traded veneer 1970-1995**



- Global production of traded veneer[3] increased from less than 5 million m³ in 1988 to more than 14 million m³ in 1994.
- Asia has become the major producer of veneer, accounting for 85% of production in 1994.

6.3.2 Furniture components

The market for furniture and furniture components is developing rapidly for both hardwood and softwood sawn timber. Modular design of furniture allows for global sourcing of components. However, in many circumstances, it is essential that a number of components should originate from the same source to ensure the matching of grain, figure, species and colour.

Currently, limited information is available on the global trade in furniture components. Traditionally, the main production areas have been the resource rich and low labour cost areas of SE Asia. However, resource availability has become increasingly important, and other regions such as Northern Europe, Eastern USA, Chile and New Zealand have started to produce furniture components.

6.3.3 Mouldings

[3] This does not include veneer used for plywood production within the same plant.

The available information on global markets for mouldings is also limited. Most mouldings are used domestically and only relatively small volumes are traded internationally. Mouldings include a diversified range of products such as picture frames, skirting boards, architraves, door and window frames. Recently developments have taken place which have resulted in increasing international trade in mouldings. These developments have included the greater international acceptance of standardised mouldings and the competitiveness of mouldings produced at the mill site rather than closer to the end user market.

About 20% of globally consumed industrial hardwood and 5% of globally consumed softwood is used in mouldings. This would indicate that the total global market for hardwood mouldings is about 10 billion board feet (25 million m^3) and for softwood mouldings about 6.4 billion board feet (15 million m^3).

6.3.4 Flooring and Panelling

The flooring and panelling markets change due to variations in fashion. They have traditionally been focused on hardwood, with softwood playing a minor role. Global flooring and panelling markets account for about 8% of sawn hardwood usage while only 1% of global sawn softwood is used in these markets. This indicates a total global market for hardwood flooring and panelling of about 4.2 billion board feet (10 million m^3) and about 1.3 billion board feet (3 million m^3) of softwood.

The global market for panelling is static as wood panelled interiors are not currently fashionable. However, the markets for flooring are expanding rapidly. With respect to panelling, feature grade, containing a number of natural defects, may present an opportunity for market penetration. Feature grades are roughly equivalent to #3B Common under the US National Hardwood Lumber Association grading rules.

6.3.5 Others

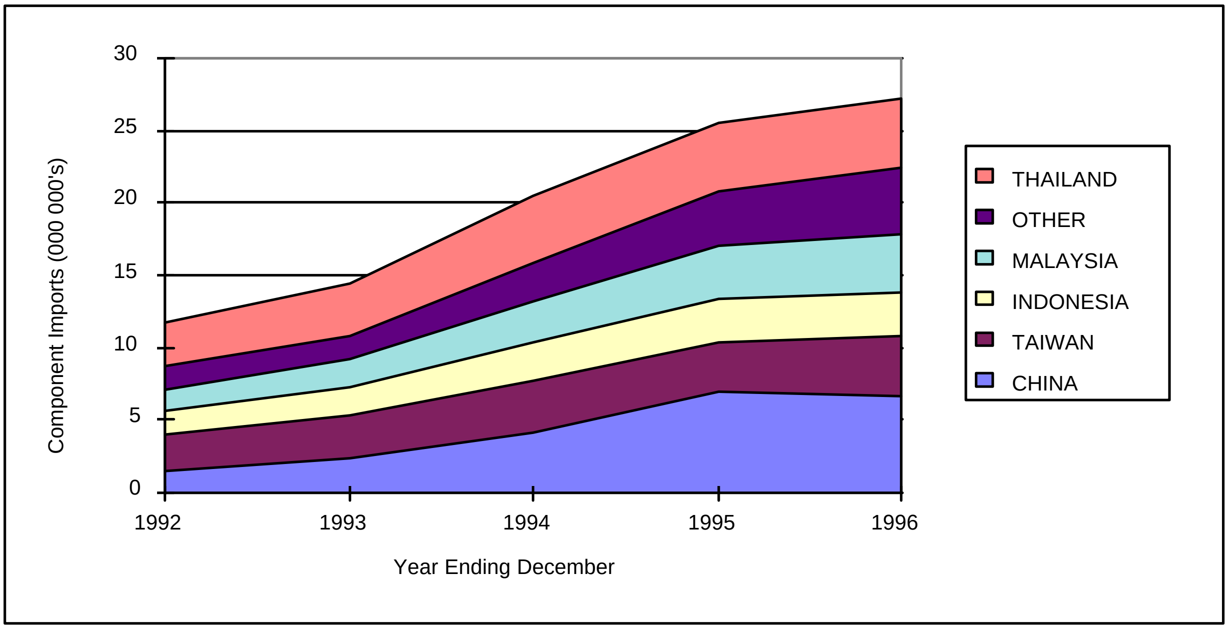
Value-added applications for hardwood are varied. Other uses such as edge-glued panels, laminated beams, laminated bench tops, parquetry, composite flooring, end matched flooring and panelling are expanding rapidly. These represent growth areas which should be given more emphasis in both production and marketing aspects.

6.4
Export Markets for Value-added Hardwood Products

This section illustrates important developments in value-added hardwood products in the main Asian markets, Japan, Korea, Taiwan and China which could present increasing opportunities for new entrants to these markets.

6.4.1 Japan

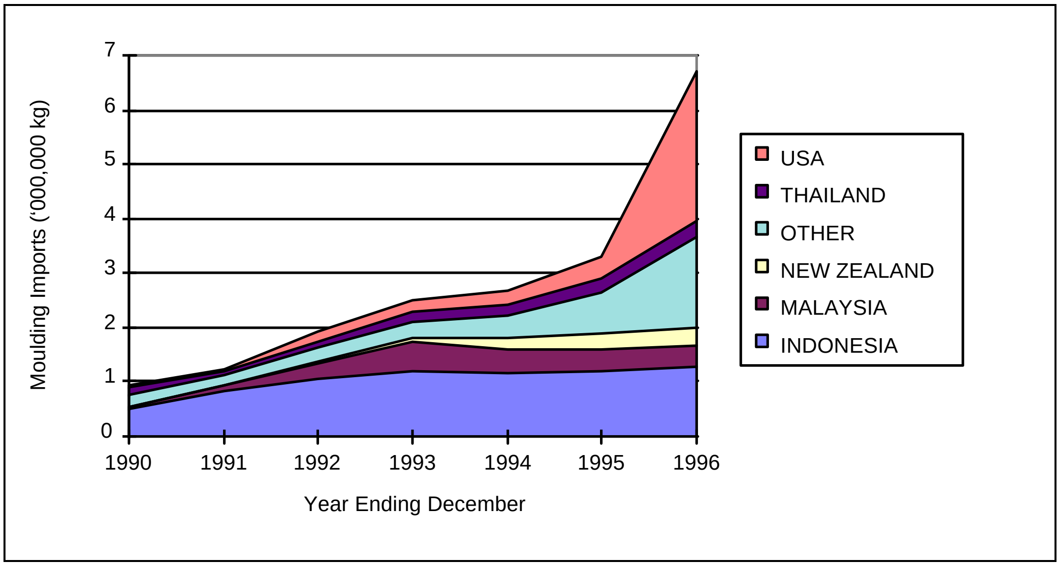
Figure 6-8: Total annual hardwood component imports into Japan from Jan 1992 to Dec 1996



Source: NZFRI WoodWide forest products database.

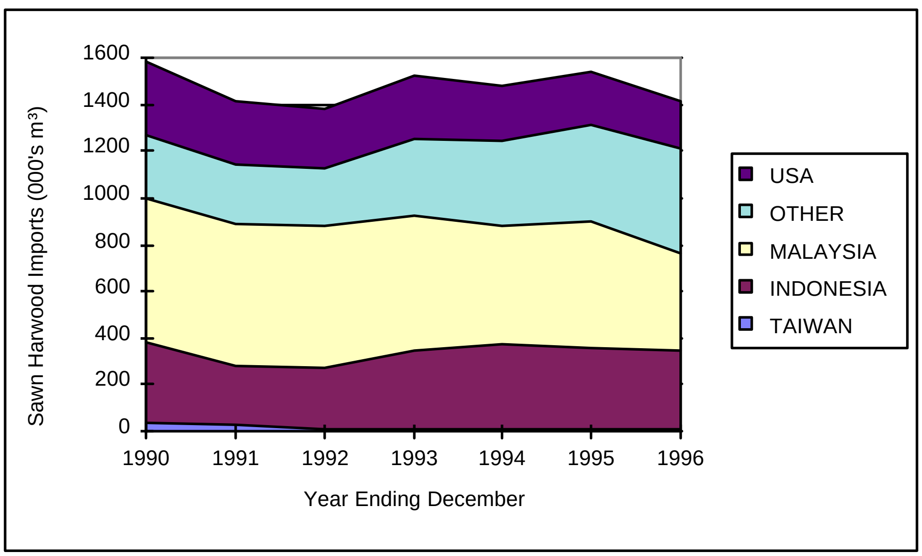
Figure 6-8 shows there has been a doubling over the past five years, in the number of hardwood components imported by Japan. Over this same period, the quantity of hardwood mouldings imported by Japan has increased six-fold, with the majority of this increase occurring in 1996 and originating in the USA (Figure 6-9).

Figure 6-9: Total annual hardwood moulding imports into Japan from Jan 1990 to Dec 1996



Source: NZFRI WoodWide forest products database.

Figure 6-10: Annual sawn hardwood timber imports into Japan from Jan 1990 to Dec 1996

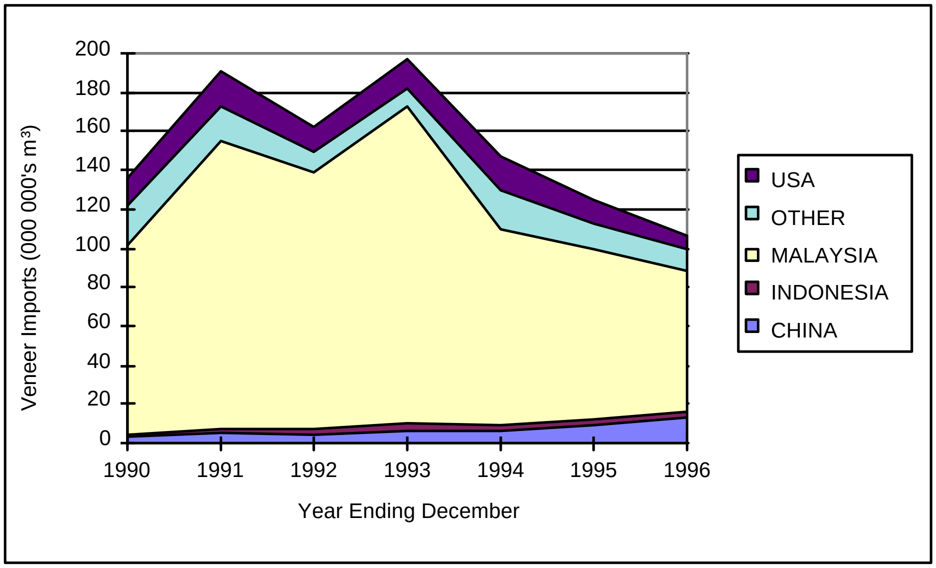


Source: NZFRI WoodWide forest products database.

The total volume of sawn hardwood imported by Japan from January 1990 to December 1996 showed only minor cyclic fluctuations (Figure 6-10). There was little change in the supply positions of the major exporters except that Malaysian supply appears to be reducing, possibly due to increasing domestic demand.

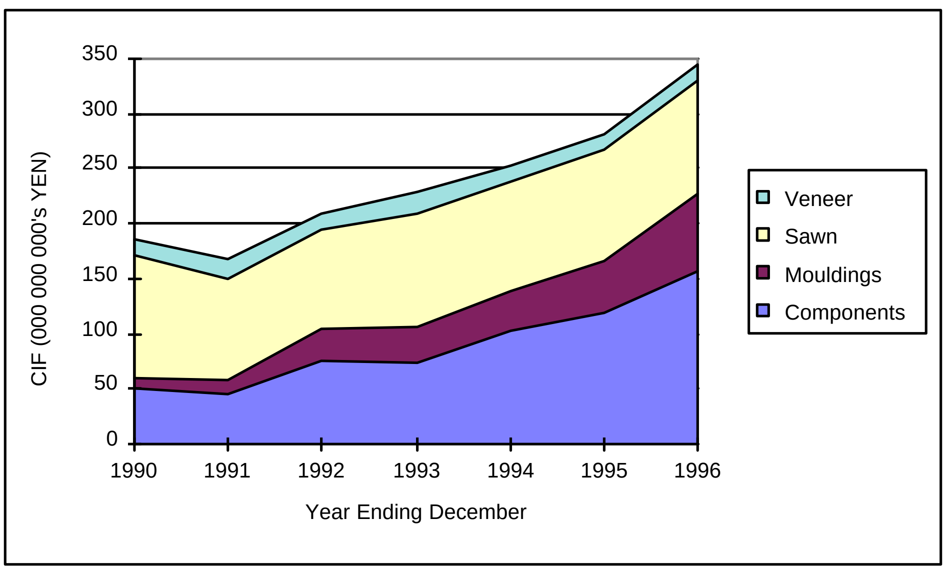
Figure 6-11 shows that 70% of the hardwood veneer imported by Japan originates in Malaysia. However, the Japanese imported hardwood veneer market has fallen by half from its 1993 peak.

Figure 6-11: **Total annual hardwood veneer imports into Japan from Jan 1990 to Dec 1996**



Source: NZFRI WoodWide forest products database.

Figure 6-12: **Total annual value of hardwood imports into Japan from Jan 1990 to Dec 1996**



Source: NZFRI WoodWide forest products database.

Figure 6-12 shows the total annual CIF value of hardwood imports by Japan. The value of hardwood mouldings imported by Japan has increased by nearly six times between 1990 and 1996. Accompanying this increase has been the replacement of sawn hardwood by hardwood components as the most valuable hardwood product group. Hardwood components are usually seasoned, dressed and finished pieces for interior use in doors, windows and other high class joinery and in furniture manufacture. They simply require putting together either in a factory or "in situ". They thus represent the ultimate in value-added production and marketing.

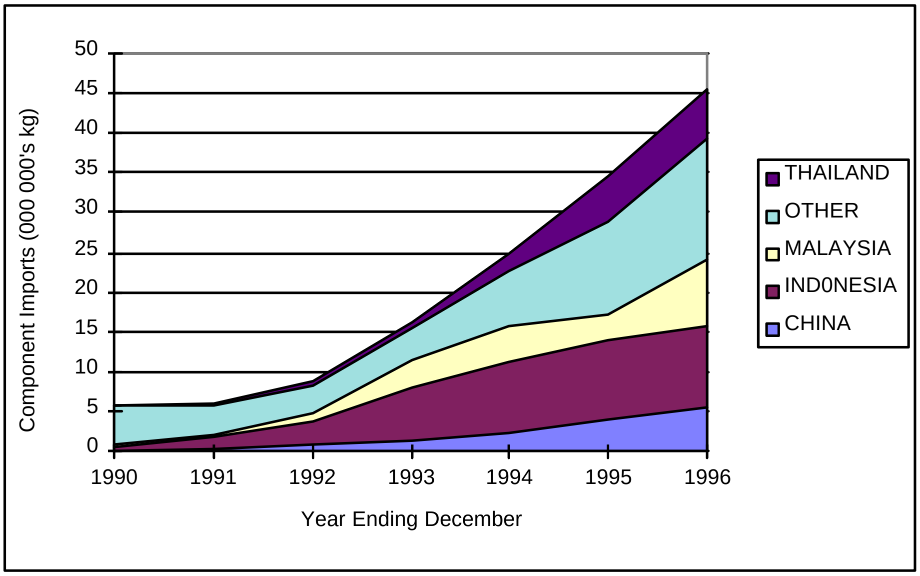
Currently hardwood component imports equal a little under half the total value of all hardwood products imported by Japan. It seems likely, in the near future, the combination of hardwood mouldings and componentry will account for 75% of the value of all Japanese value-added hardwood imports.

6.4.2 Conclusions on current hardwood import trends into Japan

- While the overall sawn hardwood market appears static, there has been significant growth in imports of mouldings and componentry.
- High labour and land costs are forcing more furniture manufacturers offshore contributing to rising imports of semi-finished products.
- The Japanese market for imported hardwood veneers is almost entirely influenced by Malaysian exports. Other exporters into this market seem to maintain their volumes during times when Malaysian exports fluctuate.

6.4.3 Korea

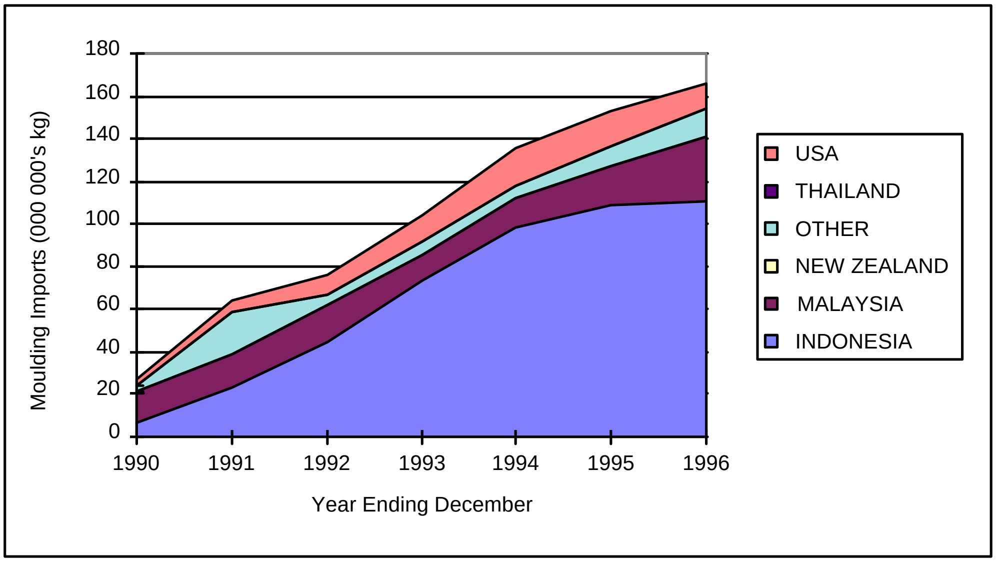
Figure 6-13: Total annual hardwood component imports into Korea from Jan 1990 to Dec 1996



Source: NZFRI WoodWide forest products database 1 million kg = 1,100 US tons

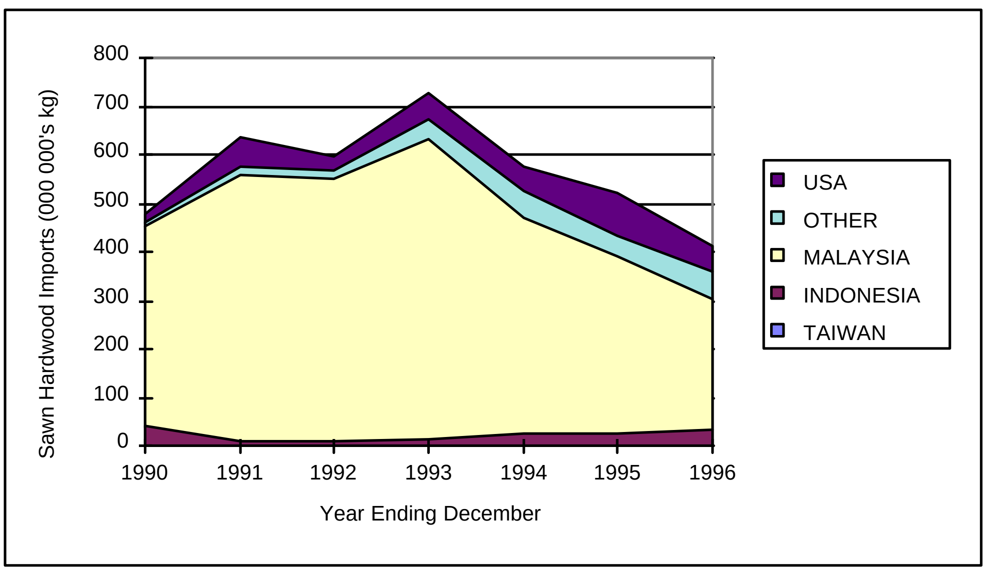
Figure 6-13 shows that imports of components into Korea have grown 900 percent since 1990, with the market exhibiting linear growth overall since 1992. The Korean market for imported hardwood mouldings has also shown dramatic growth during 1990 to 1996 (Figure 6-14). The proportion of hardwood mouldings originating in Indonesia has increased by 1100% from 11000 US tons (10 million kg) in 1990 to 120000 US tons (110 million kg) in 1996, the major increase occurring between 1990 and 1994. Other suppliers have had mixed fortunes.

Figure 6-14: **Total annual hardwood moulding imports into Korea from Jan 1990 to Dec 1996**



Source: NZFRI WoodWide forest products database. 1 million kg = 1,100 US tons

Figure 6-15: **Total annual sawn hardwood timber imports into Korea from Jan 1990 to Dec 1996**

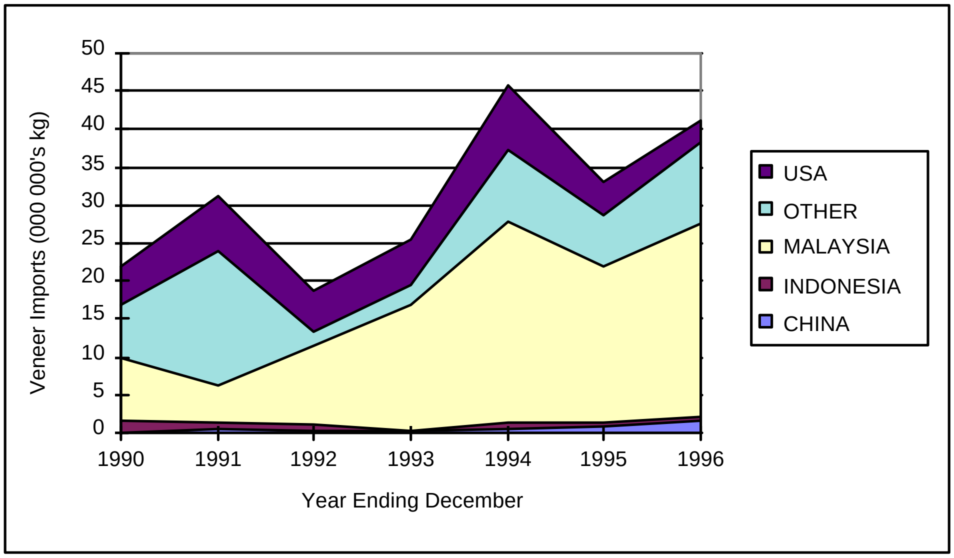


Source: NZFRI WoodWide forest products database 1 million kg = 1,100 US tons

Korean imports of sawn hardwood are mostly from Malaysia, although the quantities from this source have dropped by half since 1993 (Figure 6-15). Other suppliers have made slight market gains.

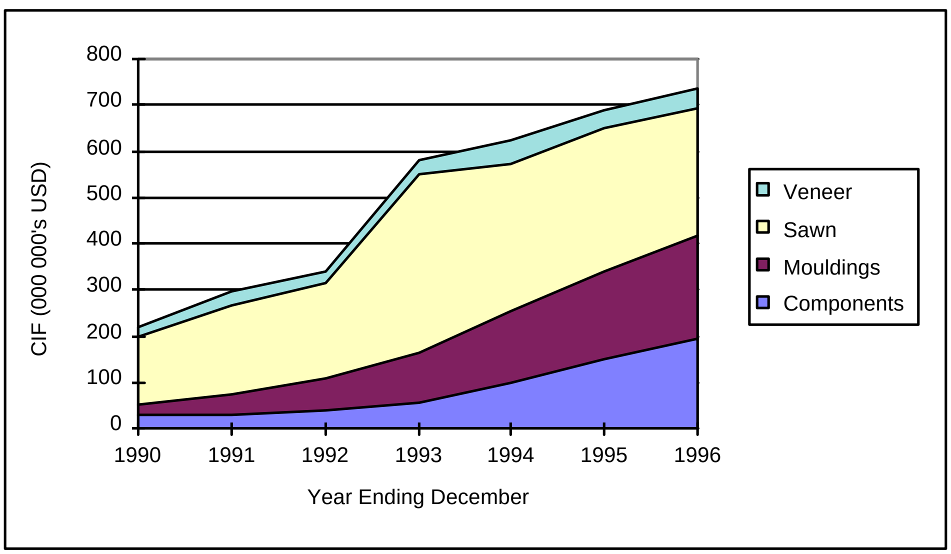
Figure 6-16 gives total annual hardwood veneer imports into Korea, and again shows Malaysian dominance. Imports originating in Malaysia have shown significant overall growth since 1992.

Figure 6-16: **Total annual hardwood veneer imports into Korea from Jan 1990 to Dec 1996**



Source: NZFRI WoodWide forest products database

Figure 6-17: **Total annual value of hardwood imports into Korea from Jan 1990 to Dec 1996**



Source: NZFRI WoodWide forest products database

Figure 6-17 shows the total annual value (CIF USD) of hardwood products imported by Korea. The major ramification for suppliers is that the combined value of components and mouldings now exceeds the value of sawn timber imports. The landed volume of hardwood components and mouldings in Korea would be much less than the volume of sawn hardwood of an equal CIF value. This suggests a lower unit freight cost involved in the export of components and mouldings to Korea, thus the opportunity to capture an increased margin may exist.

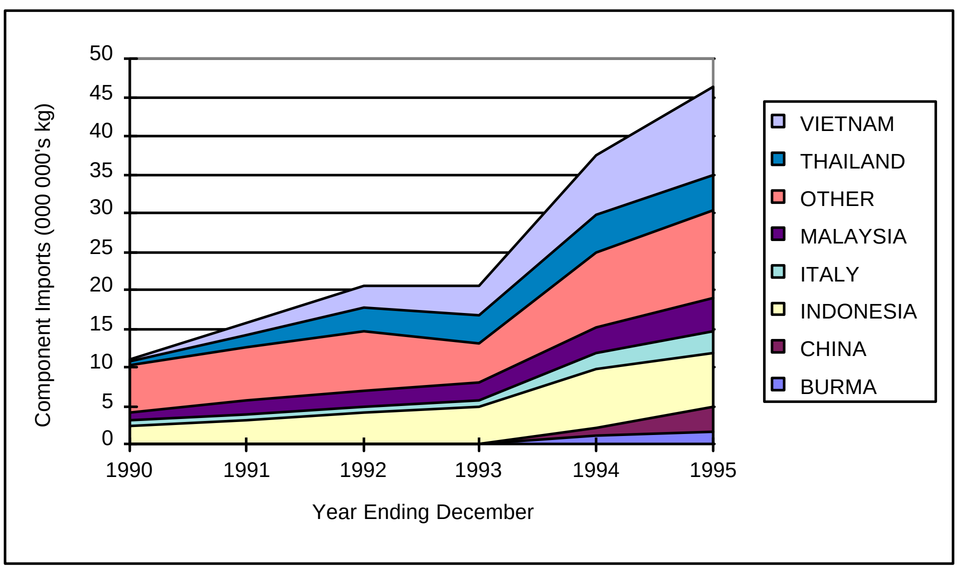
6.4.4 Conclusions on current Korean import trends

- Korean hardwood component imports from Malaysia, Indonesia and Thailand have risen from being insignificant in 1990 to over 50% of all component imports by 1996.
- The flattening of supply in tropical hardwood mouldings from Indonesia has been offset by increased supply from Malaysia.
- The value of veneer imports has shown little growth, relative to other hardwood imports.

6.4.5 Taiwan

Taiwan's total annual imports of hardwood components have grown by approximately 50000 US tons (46 million kg) in five years (Figure 6-18).

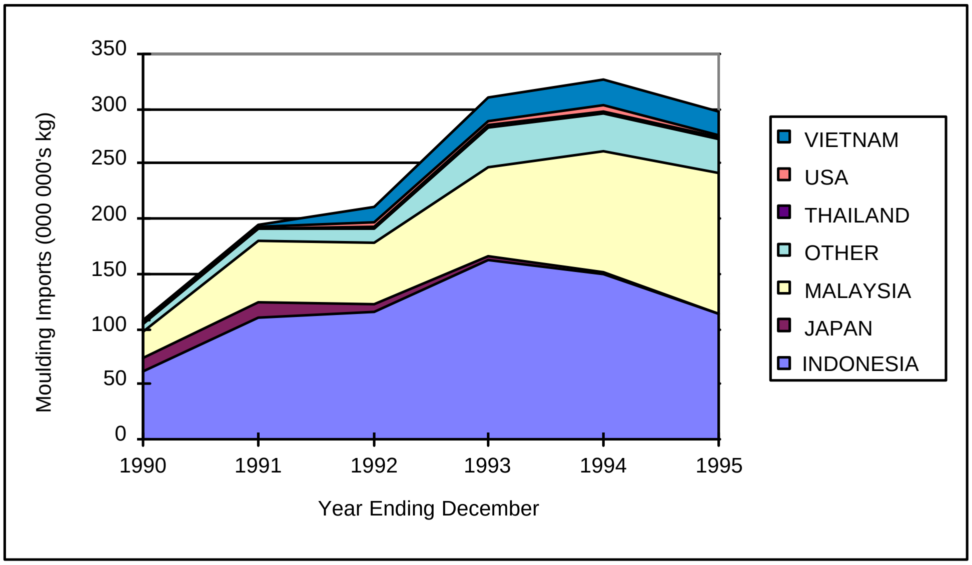
Figure 6-18: Total annual hardwood component imports into Taiwan from Jan 1990 to Dec 1995



Source: NZFRI WoodWide forest products database

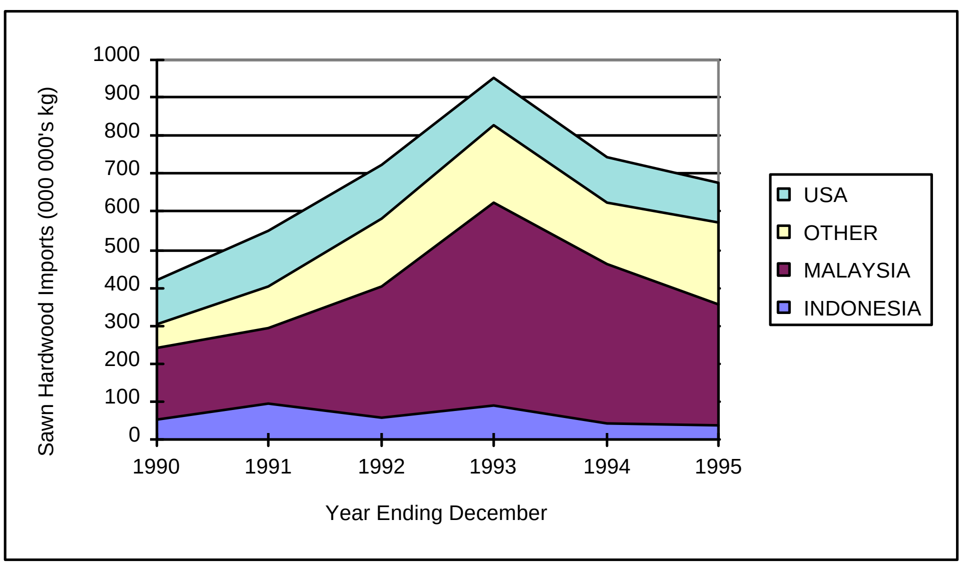
In 1993 however the total quantity of component imports by Taiwan remained static at the 1992 level. This period coincided with high global demand for roundwood, and minor suppliers of Taiwan's component imports reduced production as their raw material prices peaked. The market for mouldings showed a reduction in growth during 1995, due in the main to reduced exports from Indonesia. Malaysia has increased supply over this period, with some mitigating effect (Figure 6-19).

Figure 6-19: **Total annual hardwood moulding imports into Taiwan from Jan 1990 to Dec 1995**



Source: NZFRI WoodWide forest products database 1 million kg = 1,100 US tons

Figure 6-20: **Total annual sawn hardwood timber imports into Taiwan from Jan 1990 to Dec 1995**

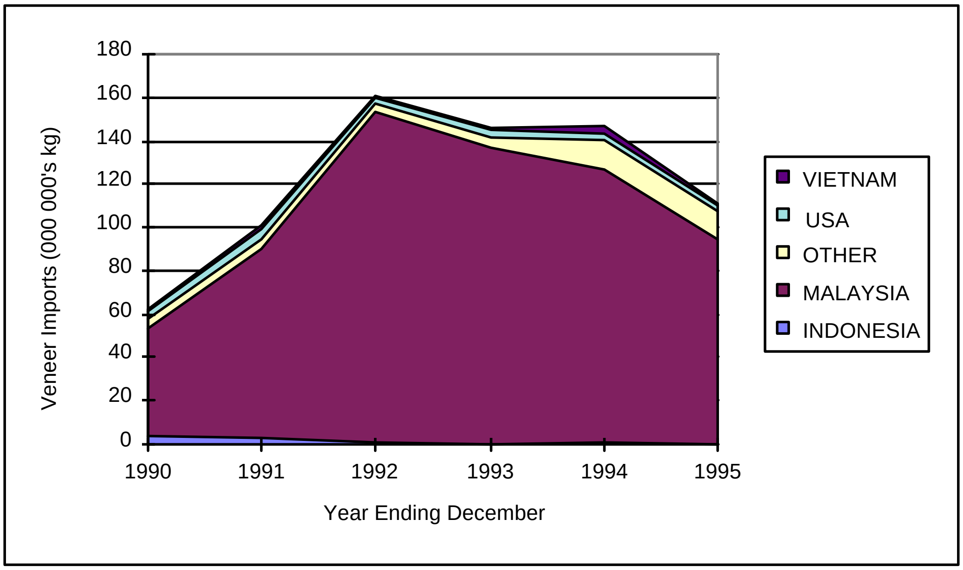


Source: NZFRI WoodWide forest products database 1 million kg = 1,100 US tons

Figure 6-20 shows the peak in Malaysian sawn hardwood timber exports to Taiwan in 1993. Quantities from other suppliers to Taiwan have remained relatively static. Opportunities may exist for new exporters to this market as Malaysian supplies continue to drop.

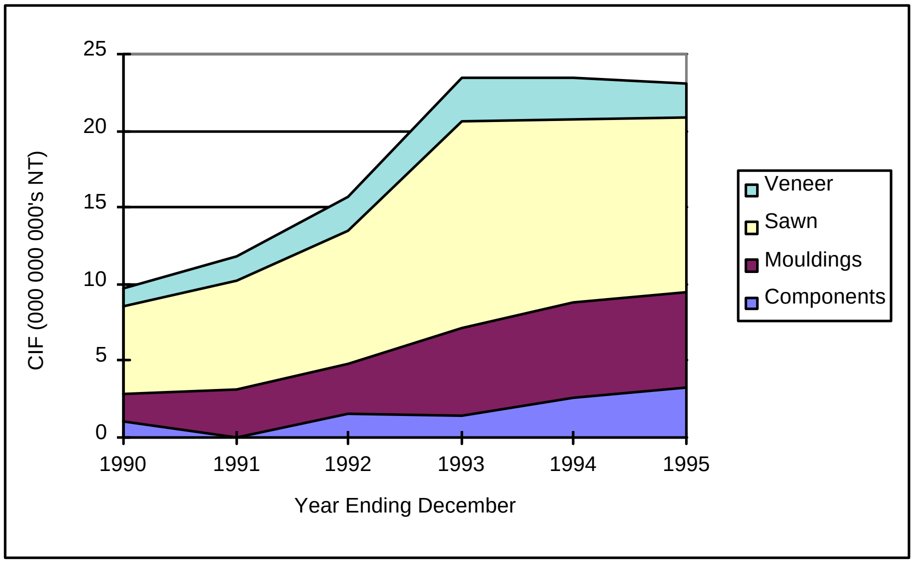
Figure 6-21 illustrates Malaysia's dominance in the hardwood veneer trade. However, the decrease in supply of Malaysian veneers since 1992 has resulted in opportunities for other market entrants, and the quantity of hardwood veneer imported by Taiwan from other sources doubled between 1993 and 1995.

Figure 6-21: Total annual hardwood veneer imports into Taiwan from Jan 1990 to Dec 1995



Source: NZFRI WoodWide forest products database 1 million kg = 1,100 US tons

Figure 6-22: **Total annual value of hardwood imports into Taiwan from Jan 1990 to Dec 1995**



Source: NZFRI WoodWide forest products database

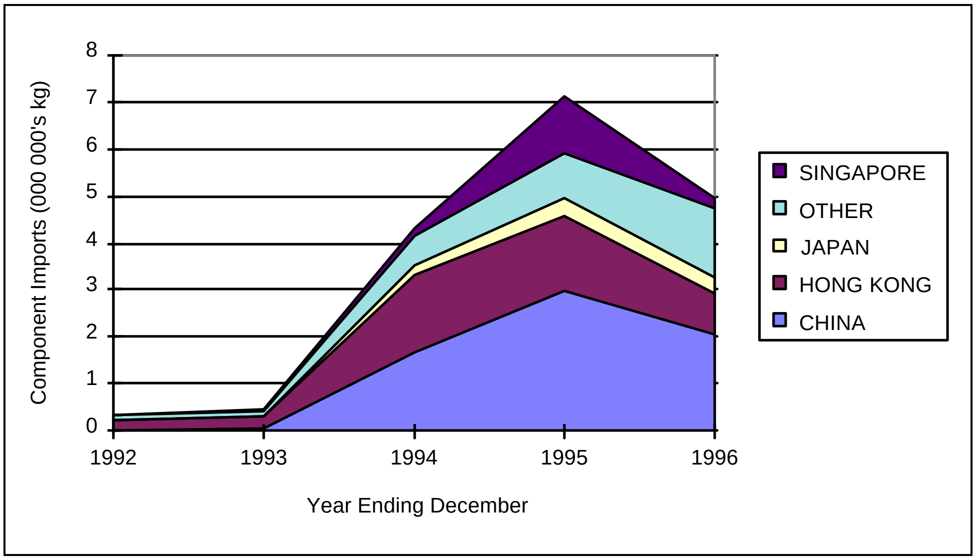
There were sharp increases in the total annual CIF value of hardwood imports from 1990 to 1993. Thereafter, this value remained static (Figure 6-22). The CIF value of sawn hardwood imported by Taiwan from 1990 to 1995, has remained at about half the total CIF value.

6.4.6 Conclusions on current Taiwan's import trends

- The total value of hardwood imports peaked during 1993/1994 in Taiwan, and has since declined very slightly.
- Value of imports increased strongly pre-1993, but has since remained relatively stable, while volumes have dropped, indicating the increasing value of imported material.

6.4.7 China

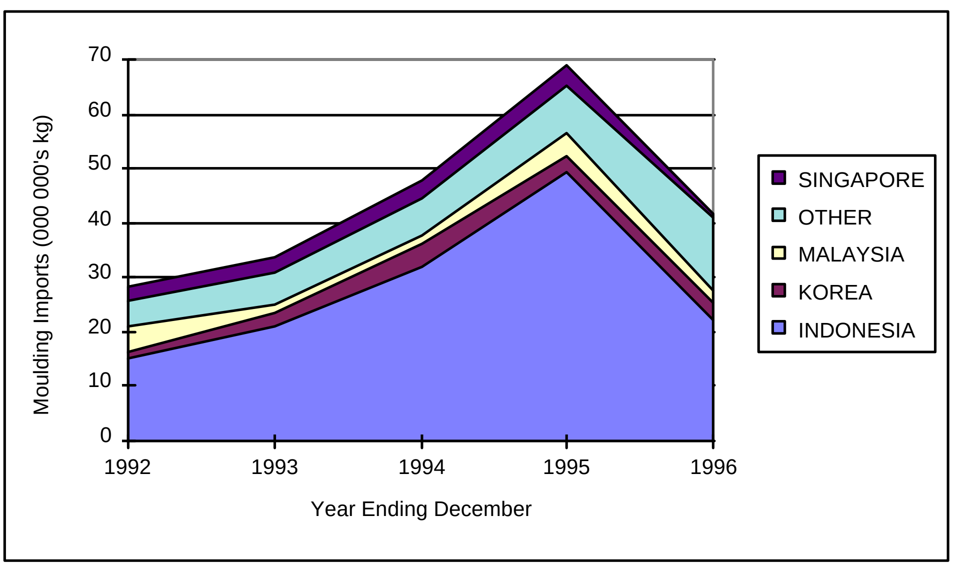
Figure 6-23: Total annual hardwood component imports into China from Jan 1992 to Dec 1996



Source: NZFRI WoodWide forest products database

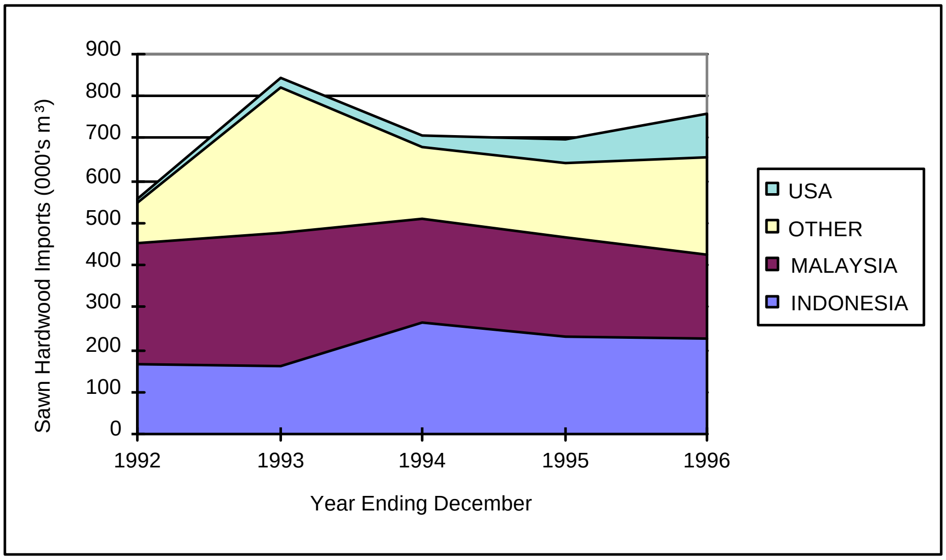
Figures 6-23 and 6-24 show a decline in imports of componentry and mouldings during 1996. In the case of mouldings, however, the decline is due entirely to falling Indonesian exports. The peak in 1995 may be attributed to increased value-added production at a time of low log prices.

Figure 6-24: Total annual hardwood moulding imports into China from Jan 1992 to Dec 1996



Source: NZFRI WoodWide forest products database

Figure 6-25: **Total annual sawn hardwood timber imports into China from Jan 1992 to Dec 1996**

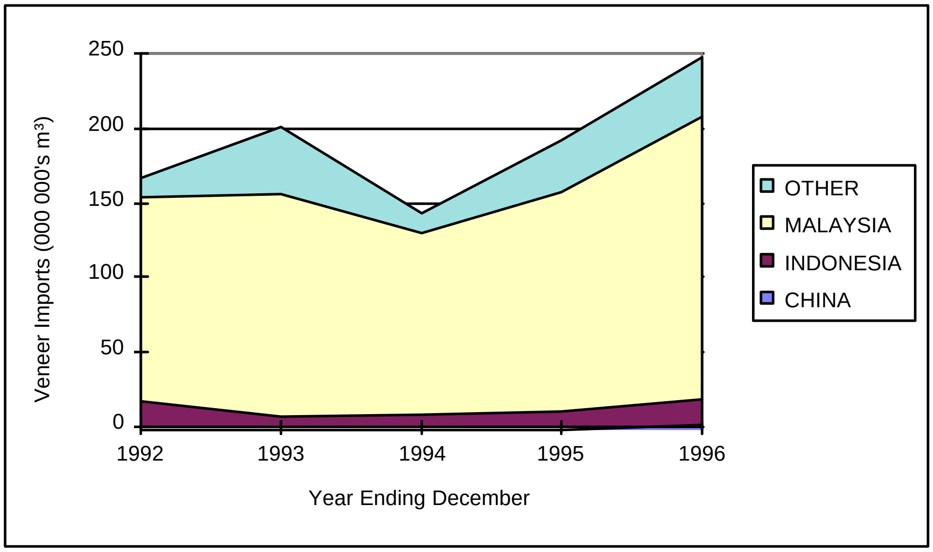


Source: NZFRI WoodWide forest products database

Figure 6-25 shows a peak in 1993 mainly arising from increased sawn hardwood exports into China from other smaller producers. During 1993 a peak in commodity log prices would have resulted in increasing returns from sawn timber that provoked higher export volumes to China. However, the combined volume of imports from Indonesia and Malaysia has remained virtually constant over the last 5 years.

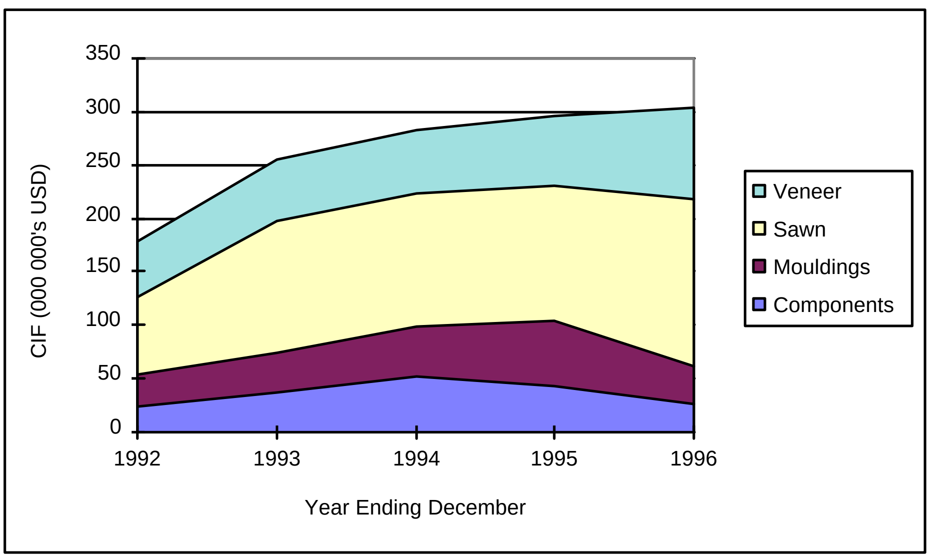
China's imports of veneer are dominated by Malaysia (Figure 6-26).

Figure 6-26: **Total annual hardwood veneer imports into China from Jan 1992 to Dec 1996**



Source: NZFRI WoodWide forest products database

Figure 6-27: **Total annual value of hardwood imports into China from Jan 1992 to Dec 1996**



Source: NZFRI WoodWide forest products database

The total annual CIF value of hardwood imports has increased from about USD 180 million in 1992 to USD 300 million in 1996. However, this increase has been against the trend in terms of the relative importance of each of the products, i.e. sawn timber has increased its share of the total while mouldings and components have reduced. This is probably a reflection of China's stage of development and the sophistication of its markets.

6.4.8 Conclusions on current Chinese import trends

- Combined CIF values for mouldings and components have risen consistently apart from 1996. However, components peaked in 1994.
- The CIF values for veneer and sawn timber have maintained a steady rise since 1992 with a relatively sharp increase in 1996.
- Overall, the total CIF value of Chinese imports seems to be flattening out.

6.5 Competition from other Appearance Grade Hardwood Suppliers

In producing value-added hardwood timber products, Hawaii would be competing at the high end of the market. The demand for these products is primarily for their appearance, although strength and durability may also be added attractions. There is a perception of "solid wood" which allied to its beauty of grain, figure, texture and colour, gives it a mystique in the market place which many other competitive materials do not have.

6.5.1 Asia (except China)

Hardwood production throughout Asia is expected to decline further. This should improve the competitiveness of overseas producers provided they build up a reputation as reliable long-term suppliers. However, the steady decrease in log exports, especially from Malaysia, coupled with forecast increases in average delivered log prices, will encourage Asian producers to emphasise profit maximisation through further value-adding.

By 2005, Malaysia will reach a critical stage with regard to its log supply, further opening up marketing throughout the Asia-Pacific region.

6.5.2 China

Despite impressive planting programs in recent years, China's wood deficit is forecast to increase, particularly since the widespread flood of 1998 and subsequent further harvesting restrictions to protect the catchments of the Yangtze and Yellow Rivers. Although hardwood exports will probably continue at a low level in order to generate foreign exchange, this is not expected to pose a major threat to current and potential markets for overseas producers.

Furthermore, as China gradually opens its doors to international trade and improves its economic performance, it will offer increasing opportunities for foreign hardwood producers. Recent restrictions on the harvesting of native forests following widespread flood damage will further reduce China's ability to supply its domestic hardwood requirements.

6.5.3 North America

Total wood production in the US North West will decrease mainly for conservation reasons. However, total hardwood production will increase, as there are large hardwood resources in eastern-central Canada and in the US South which are currently under utilised, although latterly there has been improved utilisation. This will increase competition in the North American and Asian markets. In Asia, the US hardwood exporters have been successful in recent years, greatly assisted by the marketing efforts of the American Hardwood Export Council (AHEC). American hardwoods have been extensively used in new hotels, offices and luxury apartments throughout the region. Rough sawn hardwood and further processed products are exported, about half to the furniture industry in Asia, 35% for joinery; the remainder for interior decoration. However, some of the demand comes from a furniture industry producing for the US market. The main US species exported are red and white oak, ash, cherry, tulip wood, hard maple, and walnut.

6.5.4 Europe/Former USSR

Hardwood production in this region has decreased over the last decade. In western Europe, the net annual increment of 580 million m^3 per annum (hardwoods and softwoods) exceeds the annual harvest by 170 million m^3 per annum. Due to environmental and social factors, this situation is unlikely to change.

The former USSR, particularly the Russian Far East, has potential to increase output substantially. Adverse climate will always limit production from the region, but infrastructure, social and political conditions should improve in the long term and lead to greater output. In the near term, however, hardwood production is not expected to change markedly.

6.5.5 Africa

Africa is a small player in the international wood market. Short term production increases from natural forests, albeit environmentally unsustainable, are possible in a few West and Central African countries although their unstable political situations are unlikely to lead to major investments. Only South Africa appears to have potential for sustainable increases in supply. Plantation hardwood production is expected to grow from 8 million m^3 to 17 million m^3/a by 2015 although the vast majority of this is pulpwood and mining timbers. The expected increase in domestic demand in South Africa should absorb the increase in solid wood production.

6.5.6 South America

Natural hardwoods from the Amazonian rainforests and from Central American countries are a direct competitor to other producers in North America and some Asian countries. Large increases in production are expected from Brazilian, Chilean, Argentinean and Uruguayan hardwood plantations, mainly eucalypts. These are mostly grown on short rotations to produce pulpwood, and little value-added production is expected in the near future although they could, at some stage, provide competition for Hawaiian hardwoods.

6.5.7 World total

Historic and forecast production of hardwood logs is presented in Table 6-1.

Table 6-1: Global industrial hardwood roundwood production from plantations and native forests

REGION	1970	1980	1990	1993	2010
	Production (million m³)				
	Actual				*Projected*
Asia					
China	16.0	29.2	32.8	35.4	30.0
Malaysia	19.7	29.1	41.0	44.9	20.0
Indonesia	12.5	29.9	34.9	38.5	20.0
India	11.4	17.5	21.6	21.9	10.0
Japan	18.6	12.6	9.8	6.8	8.0
Other	31.9	31.2	28.6	28.0	45.0
TOTAL	110.1	149.5	168.7	175.5	133.0
Oceania	9.7	14.0	13.6	13.3	16.5
N & C America					
USA	69.7	80.6	115.0	116.7	114.0
Other	10.7	13.5	13.0	11.3	42.3
TOTAL	80.4	94.1	128.0	128.0	156.3
S America	24.0	51.3	61.5	64.0	84.0
Europe	74.2	76.8	80.8	70.3	80.0
Russia	34.1	31.3	34.2	34.2	30.0
Africa	33.9	42.4	48.7	49.4	54.0
WORLD	***336.4***	***459.4***	***535.5***	***534.7***	***553.8***

Source: FAO: Apsey and Reed

The global forecast for hardwood production indicates that, except for Asia, most areas can expect to have steady or increasing volumes of hardwood logs produced over the next few decades, although, as mentioned before, most of the increased production in South America and Africa will be in pulpwood from plantations.

The large increases in North America will come mainly from pulpwood.

Asian production will drop considerably whilst, at the same time, an increasing proportion will be hardwood pulpwood from plantations. Sawlog/veneer logs will decrease in average size and quality.

Table 6-2, based on FAO projections, shows the Asian region will have the largest consumption of sawn timber by 2010. Over the same time regional production of sawn timber will decline.

Table 6-2: Global sawn timber consumption forecast

	CONSUMPTION (million m³)			
REGION	**1993**	**2010**	**Change**	**(%)**
N & C America	156	170	14	9%
Asia	114	208	94	82%
S America	25	39	14	56%
Europe	82	145	63	77%
Ex. USSR	36	41	5	14%
Oceania	6	8	2	33%
Africa	10	18	8	80%
TOTAL	**429**	**629**	**200**	**47%**

Source: FAO Projections

In summary, despite a forecast increase in total hardwood production in the world over the next 20 years, demand is expected to increase at a faster rate, and the amount of hardwoods suitable for sawing and veneer production is expected to fall. This is especially so in the Asia-Pacific region.

6.6 Substitution Threats

6.6.1 Wood-based panels

The main alternative to solid-wood for value-added end uses such as mouldings, doors, flooring, furniture components and laminated products, is reconstituted panels with a veneer-coating. Of these, MDF is the greatest competitor due to its good working properties, dimensional stability, ability to accept coatings and reasonable cost.

Since a wide range of raw materials can be used in manufacture, MDF production throughout the Asia-Pacific region has grown rapidly over the last ten years and is expected to continue increasing for some time. Supply is exceeding demand at present and MDF prices are low. Consequently, many MDF producers are looking to improve profitability by value-adding and the production of coated mouldings and other speciality products is increasing steadily.

Much of the MDF produced in the Asian region, however, is of indifferent quality, due mainly to the variability of raw material used. In some countries, such as China, production equipment is also often inferior. While the product is acceptable for many uses in wide panel form, it is not suitable for high quality mouldings as the surface is not sufficiently uniform to accept fine paint or veneer coatings.

Thin veneer coating of MDF mouldings requires sophisticated and expensive vacuum wrapping machinery which significantly adds to the cost of production. While the finished product is not as expensive as solid wood mouldings, the difference is much reduced and, for many buyers at the high end of the market, is insufficient to warrant the use of MDF.

Wood panels, especially MDF and particleboard, have already captured a significant part of the flooring market, and will no doubt further increase their share due to their lower price per unit floor area laid. Furthermore, composites can produce a ‘natural’ appearance in flooring previously only enjoyed by solid wood. The consumer decision to use solid hardwood flooring is therefore one largely based on willingness to pay a higher price than for a composite floor. However, the use of solid wood floors at the high end of the flooring market has increased significantly and this market is expected to continue providing an outlet for high grade hardwood timber. At the same time, composites faced with hardwood open up good marketing possibilities.

A trend toward use of composite boards is occurring in the furniture market. Cabinets, cabinet backs, drawer bottoms and table tops, which were once the preserve of solid wood or plywood, are increasingly being made from MDF and occasionally particleboard.

In summary, solid wood is losing ground to MDF throughout the Asia Pacific region. However, despite its expected lower overall market share, the reducing availability of high quality solid hardwoods is expected to provide growth opportunities for producers.

6.6.2 Non-wood products

In some parts of the world, non-wood products are making in-roads into markets where wood has traditionally been used. In Hawaii, for example, steel framed houses are competing with timber framed houses, largely because of concerns about termite attacks. Plastic, aluminium and steel products have replaced wood in window frames and door jambs, again because of their perceived durability and low maintenance requirements.

Plastics and other synthetic materials are gaining a foothold in the wood panel market, where their non-biodegradability and low maintenance are proving attractive. Some “lumber” is produced from recycled plastic on Maui and is favoured by DOFAW for waterbars in trails, and other uses.

7. Prices of Competing Products

Based on the findings in the previous sections of this report, prices for sawn and dried hardwood, structural plywood and traded veneer have been collected and compared. In an analysis of this type, determining the price point is essential to ensure comparisons are made on a like-with-like basis. Equally important are issues of quality and quantity, each of which will have a significant impact on price.

Sawn and dried hardwood

One of the key issues with these products (which is not as significant with structural plywood or veneers) is quality, both actual and perceived. Some hardwoods of very high quality have been available over a long period of time resulting in market acceptance for use in particular applications at a premium price. Species such as oak, mahogany and teak will be able to achieve a price premium. Other species, such as the meranti group from South East Asia, have traditionally commanded good prices and, although quality has fallen significantly over the last 5-10 years, some purchasers continue to pay a premium for them, solely on reputation. Unfortunately, prices for the species covered in this report will probably start below the relative value of the timber because they are not well known in the market. Only time and consistent, reliable volume and quality suppliers will overcome this.

Table 7-1 shows the prices collected for competing products in Hawaii. The wholesale price in Hawaii is 40 to 50% below the retail price and 25 to 35% off the trade price quoted (often referred to as the contractor's price in Hawaii). On the information collected, this indicates that the wholesale price will be between $950/m^3 and $1,250/m^3 for kiln dried rough sawn products (the exception is silver oak which achieves a price premium). Higher prices will be achieved with further value-adding such as dressing, moulding or production of components. These prices are below those being achieved for the traditional hardwood species such as oak and maple, however, with market acceptance, the non-native Hawaiian grown species should increase in price relative to these well known species. Importantly, the lowest priced dry hardwood in the Hawaiian market is poplar and the cost of production details shown in the following sections, demonstrate that the non-native Hawaiian grown timbers can compete at this lower end of the market.

Table 7-1: Prices in Hawaii for sawn and dried hardwoods

Price point	Product	$/m³	$/Mbf
Retail	Clear oak (DAR)	5,135	12,120
Retail	Mahogany (DAR)	2,952	6,970
Trade	*Eucalyptus grandis*	1,484	3,500
Trade	*E. robusta*	1,378	3,250
Trade	*E. saligna*	1,484	3,500
Trade	Queensland maple	1,378	3,250
Trade	Silver oak	3,604	8,500
Trade	Sugi pine	1,802	4,250
Trade	Toon	1,802	4,250
Wholesale	Clear oak (DAR)	2,800	6,600
Wholesale	Mahogany (DAR)	1,600	3,780
Wholesale	Poplar	721	1,700
Wholesale	Maple	1,272	3,000
Wholesale	*E. grandis*	955	2,250
Wholesale	*E. robusta*	955	2,250
Wholesale	*E. saligna*	955	2,250
Wholesale	Queensland maple	955	2,250
Wholesale	Silver oak	1,800	4,250
Wholesale	Sugi	1,380	3,250
Wholesale	Toon	1,380	3,250

Importantly, not all the sawn lumber produced from the non-native species will be top grade clears and therefore markets will need to be found for the lower grades. There is some green hardwood sold in Hawaii for applications such as truck decking. Wholesale prices for this specialised product range from $700/m³ to $1,100/m³ or $1,650/Mbf to $2,600/Mbf. These prices are indicative of what can be achieved for products with characteristics which meet the specific needs of a niche market. Another green lumber application is in the manufacture and repair of pallets. Hardwood pallets, although significantly heavier than softwood pallets, are more suitable where they are to be used a number of times and particularly for heavy products. Hardwood pallets are stronger and more durable. At present, softwood timber is being imported from the mainland for use in pallet manufacture and repair. We were unable to get a definite price for this imported lumber, however, it is estimated at $250/m³ to $300/m³ or $590 to $710/Mbf.

The prices being achieved for sawn and dried hardwoods in other markets are shown in Table 7-2. Unless otherwise stated, prices are wholesale.

Table 7-2: Prices for sawn and dried hardwood products in potential export markets

Markets	Product	$/m³	$/Mbf
North America	Mahogany - top grade	1,010	2,385
	Meranti - top grade	940 - 1,010	2,220 - 2,385
	Red oak - top grade	560 - 685	1,323 - 1,613
	White oak - top grade	495 - 580	1,170 - 1,363
	Maple	510 - 535	1,210 - 1,260
China	White oak	1,090 - 1,210	2,570 - 2,860
	Maple	1,090 - 1,330	2,570 - 3,140
Japan	Red oak	1,060	2,500
	Meranti	890	2,100
Malaysia	Meranti	430 - 440	1,015 - 1,040
Taiwan	Ramin	525 - 620	1,240 - 1,405
	Oak	840 - 850	1,980 - 2,005
	Maple	1,400 - 1,500	3,300 - 3,540
	Rubberwood	235 - 350	555 - 825
Australia	Eucalyptus	1,600 - 2,200	3,780 - 5,190

Table 7-2 shows that competition from other species will be greater on the US mainland than in some Asian destinations. The figures are for October 1998 and, as the local economies recover, the price for the local species such as meranti will increase in USD. Based on the current prices, Jaakko Pöyry Consulting estimates that prices for the non-native Hawaiian species studied would currently be $550-$620/m³ or $1,300/Mbf to $1,400/Mbf.

An example of the type of application of sawn and dried hardwood is flooring. Traditional hardwood flooring is usually 1" thick (19 mm actual size) giving the stiffness required to span floor joists. More recently, a number of other hardwood flooring products have entered the market. These include thinner boards (4 mm to 12 mm) which may be laid over existing particleboard, OSB or plywood sub-floors or glued to plywood or OSB resulting in a flooring sheet. Many of the newer products can be pre-finished.

Some of the species investigated have been used to produce flooring products in Hawaii and *Eucalyptus saligna* and *E. grandis* are common flooring species manufactured in Australia for domestic and export markets. Table 7-3 shows the prices of various hardwood flooring products in Hawaii and Australia. Australian producers have developed export markets in Asia and North America for 19 mm flooring products.

Table 7-3: Hardwood flooring prices - top grades

Markets	Species	Thickness	Price ($/m³)	Price ($/Mbf)	Price point
HAWAII	saligna	¾" to 13/10" (19 mm)	2,130	5,030	trade
	robusta	¾" to 13/10" (19 mm)	2,130	5,030	trade
	Queensland maple	¾" to 13/10" (19 mm)	2,130	5,030	trade
	mango	¾" to 13/10" (19 mm)	3,680	8,690	trade
	koa	¾" to 13/10" (19 mm)	5,950	14,040	trade
AUSTRALIA	saligna	19 mm	2,105	4,970	wholesale
	brush box	19 mm	2,370	5,595	wholesale
	spotted gum (citriodora, maculata)	19 mm	2,025	4,780	wholesale
	brushbox	4 mm	4,165	9,830	wholesale (pre-finished)

Table 7-3 shows prices for top grades only. Lower grades, which have some defects which affect appearance but not the structural integrity of the timber, will sell for 35-50% less than the top grade product. Timber which does not meet specification for flooring in longer lengths can be reprocessed into parquetry. Australian prices for these products are shown in Table 7-4. As with the other flooring products, Australian parquetry flooring has been successfully marketed in Asia and North America indicating that these same opportunities exist for any potential Hawaiian production.

Table 7-4: Prices for parquetry flooring in Australia

Species	Price point	Thickness	Price ($/m³)	Price ($/Mbf)
saligna and lemon scented/ spotted gum (citriodora/ maculata)	wholesale	9 mm	3,050	7,200
	trade	9 mm	3,330	7,860
	retail	9 mm	4,330	10,220
brushbox (chocolate heart)	wholesale	9 mm	2,780	6,560
	trade	9 mm	3,220	7,610
	retail	9 mm	4,330	10,220

Structural plywood

As mentioned earlier in this report, there is a significant market in Hawaii for structural plywood. The retail price in Hawaii is about $575/m³ or $1,360 per Mbf indicating a wholesale price of about $320/m³ or $755/Mbf for CD grade untreated. The current price has been affected by the oversupply of OSB on the mainland which can be substituted for plywood in many applications. Prices on the mainland USA and in Asian markets are lower than this in most cases which, at least in the short term, will probably be prohibitive for a Hawaiian manufacturer to access either local or export markets.

Prices for higher grades and treated plywood are higher in Hawaii with the wholesale price for AC treated softwood structural plywood about $430/m^3$ or $1,010/Mbf. However, locally produced higher grades will still have difficulty competing with imported products and therefore on the export markets.

Some of the Hawaiian non-native species, particularly the eucalyptus species, are suitable for the production of high strength structural veneers. These products can command high prices in niche markets. Unfortunately, these markets are small at this stage and would be difficult to access for a new producer.

Large volumes of structural plywood is manufactured in South East Asia for the Asian market using mixed tropical hardwood (MTH). The MTH plywood has a high quality surface and is used extensively in concrete formwork. It is also less dense than plywood manufactured from hardwoods such as eucalyptus providing a lighter, easier to use board. Although substitution of the diminishing MTH resource will occur, softwood plywood, possibly with a high quality hardwood face, will most likely capture much of this market. Therefore, veneer production rather than plywood may be a better option.

Traded veneers

The three potential veneer products from the species investigated are decorative veneers (slice or rotary), face veneers and core veneers. The most valuable are the decorative veneers which commonly trade for up to $3,500/m^3$. This will be very dependent on species. It is unlikely that the eucalyptus species studied will produce much volume of suitable quality for decorative veneers and will not be able to achieve the high prices enjoyed by species such as mahogany. Other species such as silver oak, toon and Queensland maple should achieve both a high volume recovery of decorative veneers and a high price.

Price for core veneers are currently around $200 to $220/m^3$ on the US mainland and similar in Asia. Face veneers suitable for the manufacture of formply, sell for about $50/m^3$ more than core veneers.

8. The unit cost of bringing a given volume of wood product to the market and relative competitiveness

8.1 Introduction

Market is defined as "a stage in processing at which the harvested, chipped, or milled and dried wood is ready for additional value-adding".

The unit cost is therefore the combined cost of harvesting the tree, cutting into logs, transporting the logs to a processing facility, processing them into a specific product and delivering the product to the market. At any stage in this process there are a number of dependent variables which can significantly influence the final unit cost.

Therefore, to derive unit costs for a range of species and products, all the dependent variables need to be identified and modelled. The dependent variables fall into the following categories:

- **Species, volume and wood quality**: Species grow in a range of sites and climates, giving a range of growth rates, optimum rotation lengths and wood qualities. These, combined with a range of management regimes, influence the unit value of trees and the logs therein.
- **Operational variables**: The cost of harvesting trees is influenced by the physical characteristics of the species (including piece size and branching habit) and by ease of access to the plantation which will be determined by topography, surface terrain features and density of competing vegetation. The scale of the operation will also impact on costs with large mechanised harvesting operations less costly per unit volume harvested than small manual operations.
- **Logistical variables**: The cost of loading, transporting and unloading logs is influenced by ground conditions and equipment used in loading and unloading, and by road quality between the forest and the mill, but most significantly by the distance from the forest to the mill.
- **Processing variables**: All the costs associated with converting delivered logs into products sold by the processor. There will often be a number of stages of production with the potential to sell products at each stage. Cost components include labour, energy, chemicals (e.g. glue), maintenance materials, overheads and capital/financing costs. Recovery rates are also treated as a cost by dividing landed log cost per unit volume by the percentage of finished product recovered. Subtracting any sales of

residues, e.g. shavings, sawdust or woodchips (i.e. negative cost) gives net wood costs as per the following:

$$\textit{Net wood cost} = \left(\frac{\text{landed log cost}}{\text{recovery \%}} \right) - \text{residue sales}$$

- **Market associated variables**: The cost of promoting, selling, warehousing and distribution of products to the customer.

Components 1, 2 and 3 combine to give the landed log cost, Component 4 the conversion costs of logs to finished products and Component 5, the distribution costs.

8.2 Landed Log Costs

Harvesting of logs in Hawaii is currently undertaken on a very small scale with costs not well defined and probably not well understood by the current operators. Many of the existing harvesting operations are carried out by mill operators rather than independent contractors with the costs not identified separately. Costs for harvesting up to the point of loading the log truck have been estimated at $15.00/m³ to $22.00/m³ or $35.00/Mbf to $52.00/Mbf (true volume - not scaled) for eucalyptus pulpwood. This is based on a fully mechanised system yielding a minimum of 140 m³/ha or 24 Mbf/acre (true volume - not scaled). The costs of harvesting sawlogs or peeler logs from a resource such as the Waiakea or Hamakua Coast will be higher, probably in the range of $25/m³ to $30/m³ or $60/Mbf to $70/Mbf (true volume - not scaled). This is due to the more scattered nature of the resource compared to short rotation pulpwood and the higher costs of servicing (trimming, bucking and cutting out defects) sawlogs.

Transportation costs for sawlogs or peeler logs from the forest to the mill will be about $7.00-$9.00/m³ or $16.50-$21.00/Mbf based on an average haul of 50 km. This is also based on the use of dedicated log haulage trucks which would be engaged full time. Haulage using multiple purpose trucks on a part time basis would be more expensive. No costs have been included for any barging between islands which would increase costs significantly.

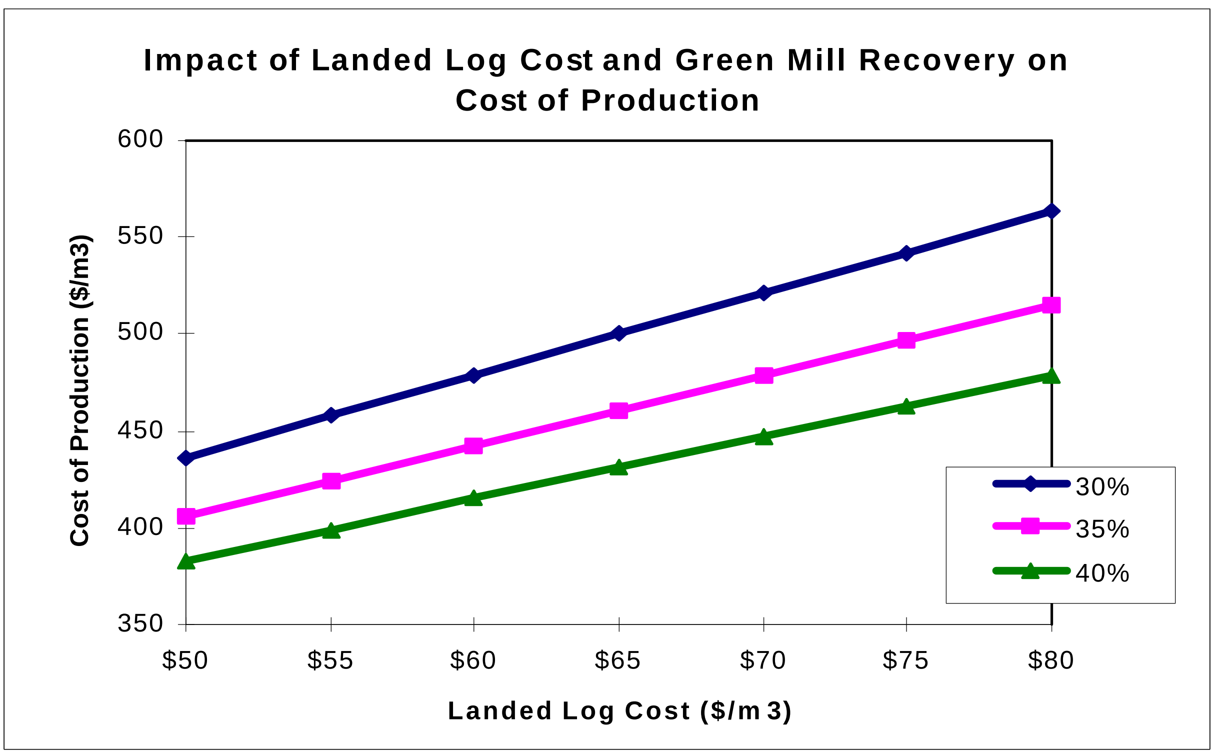
Where commercial forestry is practised throughout the world, the most efficient harvesting and haulage operations are carried out by independent contractors. These contractors may be engaged by the mill which purchases the logs but are more commonly engaged by the forest owner who will supply the customers on an on-truck or delivered to mill gate basis. This gives the forest owner better control over the final destination of the logs, particularly where multiple products are being utilised for their highest value. It also gives the forest owner better control of protection and environmental issues.

The cost of harvesting and transport does not include any costs associated with site preparation and replanting.

8.3 Conversion Costs

As mentioned in the introduction to this section, landed log costs, the recovery percentage of finished products and the sale of any residues are important components in the calculation of production costs. To determine the landed log costs, we must add to the harvest and haulage costs a stumpage amount. For the purposes of the cost competitiveness calculation and comparison, we have used $35.00/m³ or $82.55/Mbf (true volume - no scaling) as the stumpage figure. This is based on the price paid by Australian log processors for similar logs. The production cost of the finished product is sensitive to stumpage. (Figure 8-1). Again, the cost of site preparation and replanting has not been included here. If this is a requirement for the log purchaser, their capacity to pay stumpage is dramatically reduced.

Figure 8-1: **Impact of landed log cost and green mill recovery on cost of production**



Total production costs for sawn hardwood products are estimated at just over $400/m³ or $944/Mbf.

Conversion costs for the production of veneers and plywood are similarly sensitive to landed log costs and recovery rates. Total conversion costs for plywood manufacture are estimated at around $450/m³ which would make a new mill cost competitive in international markets, again based on the assumption of stumpage of $35.00/m³ or $82.55/Mbf (true volume - no scaling). Oversupply of OSB and plywood has pushed the market price down towards the cost of production. The conversion costs are estimates only based on the information available. Production costs for veneers was not able to be determined due to lack of suitable data, however, the competitiveness should be similar as for plywood with the exception that the Hawaiian disadvantage with respect to distribution costs will become more significant due to the lower value per unit volume of veneers compared to plywood.

Much more critical in the competitiveness of veneers is the recovery rates of the various grades. High recovery rates of decorative veneers will result in much higher profitability. If the resource produces high volumes of core veneers, profitability will be much lower.

The other major components of the conversion cost are production, maintenance and administration, labour, energy, chemicals (e.g. glue), maintenance materials, other consumables and capital costs. The relatively high cost of labour in Hawaii places it at a disadvantage over some countries with which it will have to compete. This will be offset in part by the stable investment environment in Hawaii, particularly when compared with Asian countries.

8.4 Distribution Costs

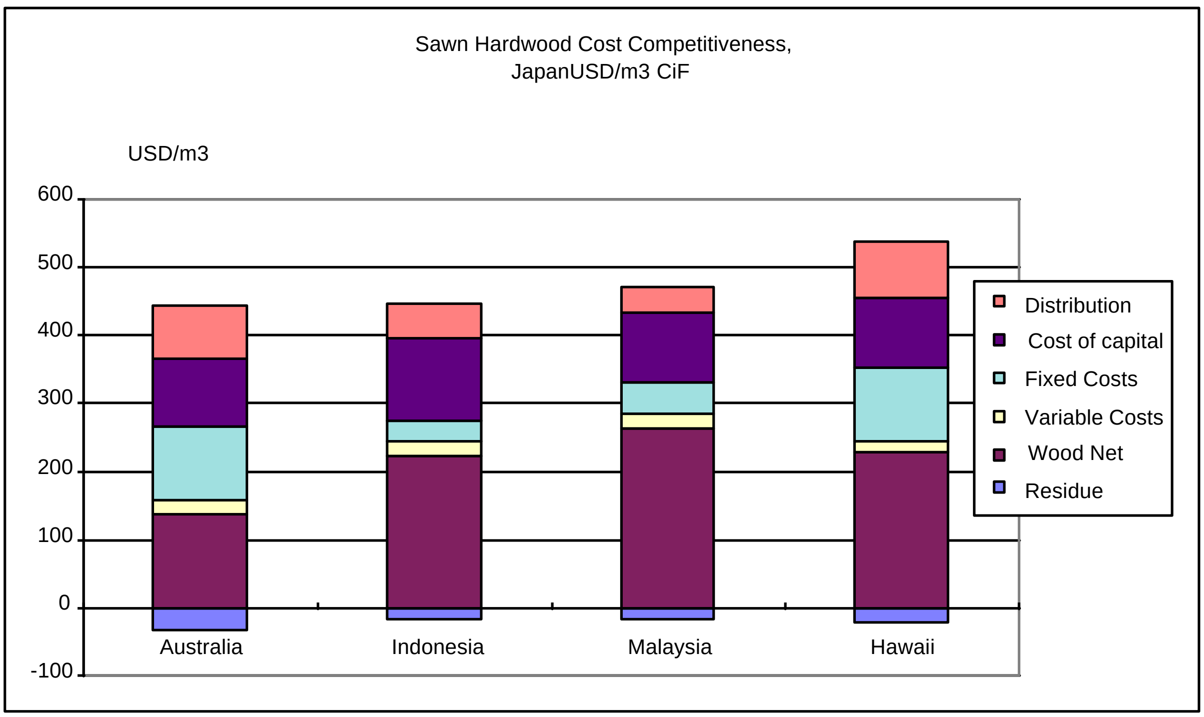
Distribution costs will vary significantly depending on the location of the market. As discussed earlier, production from a new investment in Hawaii would exceed local consumption so export markets would need to be identified. Within the Asia Pacific region, Japan is one of the major consumers and traders of wood products, so it is a good benchmark for cost competitiveness. If products can be delivered competitively to the Japanese market, then they are likely to be competitive in other Asian markets and with potential imports into Hawaii.

The distribution costs, combined with the production costs are shown in Figures 8-2 and 8-3.

8.5 Relative Competitiveness

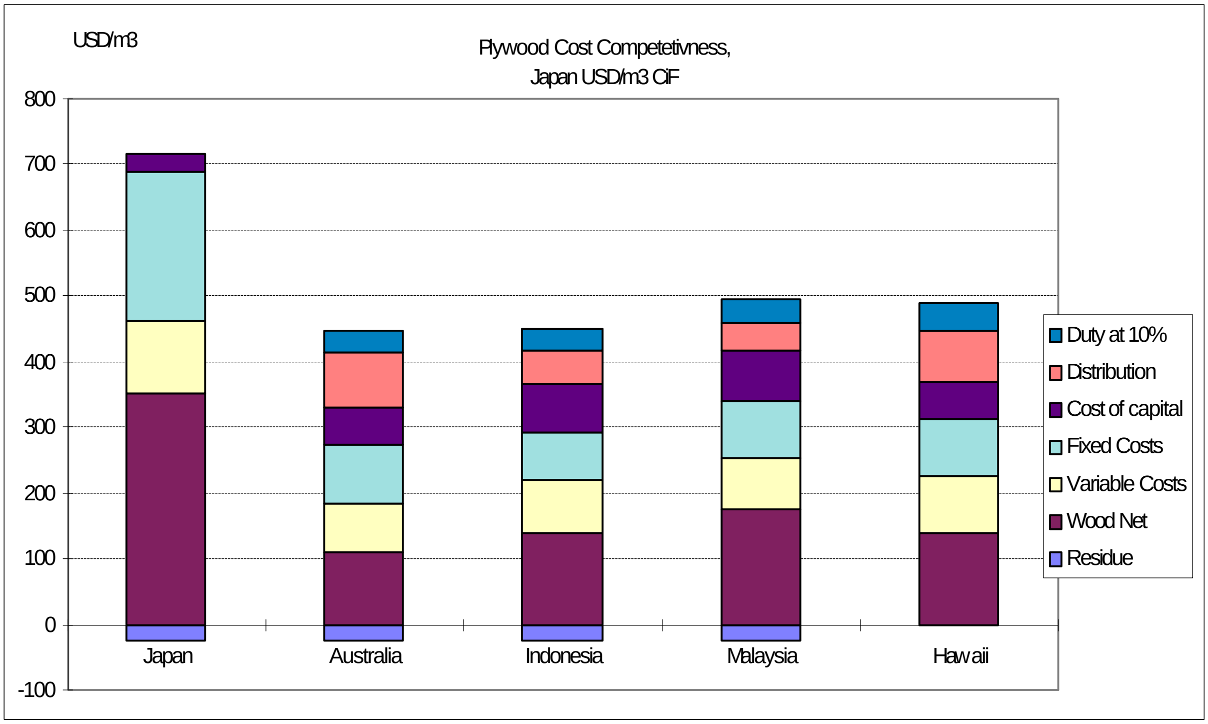
Figures 8-2 and 8-3 show the relative competitiveness of Hawaiian manufactured sawn hardwood and plywood respectively. It shows, based on the assumptions mentioned earlier, that Hawaiian production of these products should be able to compete in Asian markets and with imports. The plywood figure also gives an indication of the competitiveness of veneers produced in Hawaii. Importantly, international competitiveness is heavily influenced by exchange rates which have seen major fluctuations in some of the competing countries. Care must be taken with these comparisons, although currency movements may have compensating effects, e.g. a drop in currency value will reduce relative production costs but may also increase capital costs.

Figure 8-2: Sawn hardwood cost competitiveness, Japan USD/m³ CIF



The landed log costs (including stumpage) in Australia for similar quality logs is USD40 - 50. To be competitive in Asia, Hawaiian logs must be close to this price range.

Figure 8-3: Plywood cost competitiveness Japan, USD/m³ CIF



8.6
Scale Requirements

Table 8-1 shows the resource requirement for various world scale processing industries.

Table 8-1: Resource requirements for various wood processing industries

	Log input requirements (m^3/a)			
Industry type	**World scale range**	**Appropriate for Hawaii**	**Output**	**Capital expenditure USD millions**
Bleached kraft pulp mill	3,000,000	3,000,000	600,000[3]	750
Kraft linerboard	1,200,000	1,200,000	300,000[3]	380
Integrated TMP/Newsprint mill	1,100,000	1,100,000	450,000[3]	400
Softwood sawmill	400-500,000	400,000	150,000[1]	60
Orientated strand board	400-650,000	400,000	200,000[1]	90
Export sawlog operation	250-500,000	250-500,000	250,000[1]	2
Medium density fibreboard	250-400,000	300,000	165,000[1]	100
Particleboard	250-400,000	320,000	200,000[1]	80
Export woodchip operation	250-500,000	250,000	235,000[2]	5
Ply/veneer mill	120-200,000	150,000	100,000[1]	40
Laminated veneer lumber	120-150,000	120,000	80,000[1]	40
Integrated hardwood sawmill	30-50,000	30,000	12,000[1]	10

[1] = m^3 [2] = tonnes [3] = air dry tonnes

Some operations can be cost efficient at smaller scales but it is important to understand that the international trend is for increasing scale. For example, the log input capacity of a recently built plantation hardwood sawmill in Australia is 140,000 m^3 of logs per annum.

Scale is only important in reducing costs and may, in fact, bring about a reduction in quality and flexibility in the production of the finished product. There is an existing industry in Hawaii based on small scale niche markets. Those who manufacture for these markets focus on quality and service rather than price. It is our experience that these operations will continue to exist because they service a market which cannot be done by a large scale operation. Also, from an economic viewpoint, these manufacturers will have a higher capacity to pay for resource and therefore should be able to maintain supply.

The development of the Hawaiian industry should take these smaller operations into consideration, particularly in relation to ensuring access to the highest value species such as *Flindersia brayleyana* and *Toona ciliata*.

It must also be remembered, however, that these types of processors are unlikely to be internationally competitive and are unlikely to provide significant employment opportunities.

9. Marketing Plan

The following marketing plan outlines the major components required by the Hawaii forest industry to successfully bring its commodity wood products to market. This marketing plan is for sawn and dried products which may be rough sawn or further processed into dressed or moulded products, or components and covers the following species:

- *Flindersia brayleyana* (Queensland maple)
- *Grevillea robusta* (silver oak, southern silky oak)
- *Toona ciliata* (toon, Australian red cedar)
- *Fraxinus uhdei* (tropical ash)
- *Eucalyptus robusta* (swamp mahogany)
- *Eucalyptus saligna* (saligna, Sydney blue gum)
- *Eucalyptus grandis* (rose gum, flooded gum)
- *Cryptomeria japonica* (sugi).

The plan outlines a series of actions and outcomes that will be required to successfully market these species in both the domestic and international markets.

Sawn dried and dressed products may not be the final use for many of these species. As discussed earlier in the report, veneer and/or plywood production also presents opportunities for a number of these species. Where the issues relating to the marketing plan differ for veneer and/or plywood, this will be dealt with specifically in the following text. Where plywood and veneer are not specifically mentioned, it can be assumed that the issues are the same as for sawn, dried hardwood lumber.

9.1 Forest Resource Issues

This study has revealed the relatively poor quality of the resource information available for the Hawaii plantations. Reliable forecasts of future, sustainable yields from the plantations are essential to developing a marketing plan.

This information must contain data on:

- species
- age
- woodflows by log product.

It should combine both the public and private plantations, as developing separate marketing plans will result in unnecessary duplication and competition, and the loss of potential scale advantages.

Scale is becoming increasingly important in the timber industry throughout the world. Larger, more efficient mills are replacing smaller ones in many countries. The Hawaii forest products industry will only have the opportunity to develop the most appropriate type and size processing facilities if the investors in these facilities have confidence in the projected log volumes available to them. It is only with the appropriate type and scale of mill that local processors will be able to compete with imported products and on the export market.

Log quality (primarily determined by log diameter) is also important as it will influence the type of sawmilling equipment required to process the logs, the cost of processing (particularly in relation to volume recovery) and the types of sawn timber products produced (i.e. grade recovery). Again, reliable forecasts of log quality are essential to attract investment in processing and for the ongoing viability of that investment. The issues of volume and grade recovery are equally important for veneer and plywood production.

Finally, the potential expansion of the resource base is important in the marketing plan. Increasing future availability of resource gives investors in processing confidence that they will have the ability to expand. This will require decisions by the grower on what species to replant, the silviculture to be employed and any expansion of the estate. As with all the resource issues, these decisions should not be made without considering Hawaii's other log suppliers.

9.2 Harvesting and Delivery

The marketing plan must cover how the forest products are to be harvested and delivered to processing centres. There is, at present, limited infrastructure development within the plantations. Further development of roads will be required, however, the quality of the roading network, and consequently the cost of construction, will depend on the types of vehicles used to haul the logs.

Likewise, the harvesting technology employed will need to be determined. Equipment suitable for harvesting on steep slopes will be required. This is, however, the most expensive equipment to purchase and usually has lower productivity resulting in high harvesting costs. Ideally, the equipment required for steep areas should only be used in these conditions with less expensive, more productive equipment used on the flatter areas. Careful planning of harvesting operations is essential, therefore, for minimising costs.

Scale is also important with larger harvesting operations generally more efficient and therefore less expensive than many small operations.

The most efficient location for log segregation is in the forest. Log segregation or merchandising involves cutting logs which meet certain specifications in the forest and delivering these logs direct to the end user. Segregation classes will be determined by:

- species
- end use, e.g. sawlogs, peeler logs, poles
- size, e.g. small pulpwood and large sawlogs
- level of defect, some highly defective logs may still be sawn but this may occur at a different mill.

Ensuring that logs are cut to the correct specification and sorted in the forest results in the maximum value being extracted from the plantation and the logs being utilised for their highest value end use.

Planning and control is also essential to ensure that harvesting operations do not cause unacceptable environmental damage. A “Code of Forest Practice” could be developed to provide guidelines on how to harvest without damaging the environment and set maximum levels of soil disturbance. However, the “Best Management Practices for Maintaining Water Quality in Hawaii” is an adequate document provided it continues to be implemented and enforced. The addition of details on minimisation of stand damage during thinning operations would enhance this document.

The development of a Code of Forest Practice will also assist in getting “green” accreditation for the final products derived from the plantation. Although accreditation (also referred to as certification or ecolabelling) is not yet essential for forest products, it is becoming increasingly important, particularly in Europe and North America. It is only a matter of time before only ecolabelled products have access to some markets in Hawaii and Asia and that there will be a price premium for ecolabelled forest products (or a discount applied to non-labelled products). The plantation resource in Hawaii is well placed to take advantage of green labelling opportunities.

9.3 Processing

As stated in the introduction to this section, the marketing plan is based on the production of sawn timber products from the state owned plantation resource. The options considered in reaching this conclusion also included wood chip export, log export, rotary peeling for plywood and LVL production, slice veneering for decorative applications.

The export options as either wood chips or logs have been rejected as they do not take advantage of the value of the resource with respect to the potential value of the end use product nor the opportunity to develop a domestic processing industry. The volumes available as a by-product of sawn timber production are insufficient to support an export woodchip operation. There may be opportunities in conjunction with private growers and, as the cost competitiveness charts show, the sale of residues either as woodchips for wood panel or paper manufacture, or as biofuels, offsets wood costs and lessens the impact of low recoveries.

After careful consideration, the options of producing veneers from the resource was considered the poorer option for the following reasons:

- a relatively low proportion of the total resource of a quality suitable for veneer production
- the high level of R&D required before the industry could invest in processing
- the high capital cost of LVL or plywood mills
- lack of sufficient volume for a competitive mill.

The reasons for choosing sawn timber as the best processing option were:

- product is most suited to the scale and quality of the resource
- potential for a high level of log utilisation
- knowledge of markets for sawn timber products from these and similar species, both domestically and in export markets
- capital cost of establishing processing is not prohibitive
- potential for staged implementation, i.e. sawing and drying as a first step followed by dressing, moulding, compost production, finger jointing, edge laminating etc.
- the cost of production will be competitive with imported products.

Although our findings suggest sawn timber provides the best alternative at this stage, markets can change quickly and opportunities regularly open up. Given the difficulty in attracting investment into the wood processing industry, any proposal for veneer and/or plywood production in Hawaii should be strongly encouraged.

There are three stages along the production chain where sawn products could be sold, green rough sawn, dry rough sawn and dry, dressed or moulded. At each stage, the timber should be graded to ensure that the most appropriate products continue onto further processing and those which are unsuitable are sold.

Green rough sawn

Products which will not be suitable for further processing should be graded out at this point. Common reasons for removing green timber for further processing are:

- knots
- other defects which may result in breakages further down the production line
- excessive gum pockets or gum veins
- excessive sloping or spiral grain.

It is pointless adding further processing costs to these pieces of timber as they will only produce unsaleable products at the end of the process. Markets will therefore need to be developed for this lower grade green sawn product. Possibilities including:

- packaging and pallet timbers
- landscaping timber
- fencing.

Some species will produce relatively high proportions of green sawn products, for example, *E. robusta*, where as others, such as *T. ciliata*, will produce very little.

Green sawn production costs will be between about \$250 and \$300/m^3 (\$590-710/Mbf). An unknown volume of softwood is imported into Hawaii for the manufacture and repair of pallets. This could be substituted by locally produced hardwood, particularly where strength and durability is required and weight is not an issue.

Dry rough sawn

Timber in the dry rough sawn state is in an intermediate phase of production as it will almost always be processed further, i.e. dressed or moulded, prior to its end use application. The exception is where the dry rough sawn timber will be used in a structural application. This is common for softwoods but rare with hardwoods, particularly the Hawaii plantation species.

We are not proposing that structural applications be targeted as the end use for the Hawaii plantation species. The experience in Australia is that kiln dried structural hardwood has provided an intermediate stage between production of green sawn structural products and kiln dried, decorative products such as flooring, mouldings and furniture components. Kiln dried structural hardwoods (eucalypts) are unlikely to be able to compete with softwoods in most applications except where high strength is required. Although this may be the case in some Hawaiian building applications due to the high wind loadings experienced, it would require a major change from current building practices and place the Hawaiian plantation hardwoods in direct competition with imported softwoods.

The alternative application of these timbers as dried and dressed decorative products allows for the sale of kiln dried, rough sawn timber to other downstream processors or further processing at the mill. Purchasing timber as kiln dried rough sawn products is often preferred by some manufacturers due to:

- the full range of lengths, thicknesses and widths of finished products required cannot be efficiently produced at the mill
- opportunity to use off-cuts and downgrade material in manufactured products, e.g. cupboard backs
- greater opportunities to match colour and features
- lower stock holding requirements.

Purchasers of dry rough sawn timber tend to do a high level of further processing. For example, dry rough sawn timber may be dressed or thicknessed, straight line edged, edge glued, docked into components or finger jointed. It is less common for purchasers of dry rough sawn timber to produce the more commodity type products such as mouldings, flooring and panelling.

Dry dressed and moulded

One of the greatest opportunities for the Hawaiian plantation timbers is the production of dry dressed products in the form of mouldings, decking, panelling and particularly flooring. These products take advantage of the specific characteristics of these timbers, particularly their colour, feature, hardness, durability, high quality surface finish and (if processed correctly) dimensional stability.

These products are best produced where they are sawn, provided that the sawmill produces sufficient quantities to fully utilise the equipment necessary. Alternatively, a number of sawmills can feed dry rough sawn products into a central processing centre.

Grading

The marketing of each of these products will require the development of grading rules or the application of some existing standards. This is least important for green sawn products, particularly if they are not being used for structural applications. Dry rough sawn products are occasionally sold as a "run-of-mill" grade, however, most customers require specific quality standards. For dry dressed and moulded products, a grading convention is essential. It would be desirable if all products could be graded as per the American Hardwood Lumber Association rules. This existing standard is recognised in mainland USA and in Asia partly as a result of the work of the American Hardwood Export Council. To ensure the chosen grading rules are adhered to, each processor will need to have a quality assurance (QA) process in place. Ideally, this would be an internationally recognised, third party audited QA system. (There are a number of international organisations which provide assistance in establishing quality systems and independent auditing. These are not industry specific and concentrate on procedures to ensure consistent and measurable quality, not necessarily high quality).

9.4 Assistance

These are opportunities for government to assist the development of the industry in Hawaii. Experience has shown, however, that there is no long term benefit in support for a business which is not competitive. Any assistance should therefore be aimed at reducing or eliminating any factors which reduce competitiveness or enhancing any natural competitive advantage.

Commonly, assistance with the provision of appropriate infrastructure is most effective in increasing competitiveness. Often there is a tangible benefit to the community and other industry where there is an improvement in infrastructure.

9.5 Promotion

A new Hawaiian based forest industry will need to utilise all the normal methods of promotion such as brochures, literature, samples and attendance of international trade shows. Most success has, however, been achieved through targeted marketing which has identified customer types or individual customers, assessing their needs and providing supply of consistent quality and quantity. The American Hardwood Export Council has been extremely effective in this area and their success should be studied and, where possible, utilised by the Hawaiian industry. The Australian industry has also had success through targeted marketing in both Asia and mainland USA. Importantly, this has not only been in the top grade clear products but also in the traditionally harder to sell grades which contain some defect. Promotion of “Heritage”, “Australiana” and “Natural Feature Grades” has opened up new and profitable markets for Australian producers.

9.6 Residues

This report has mentioned the importance of residues, both forest and mill, particularly in relation to reducing net wood costs. The development of a residue using industry(s) in conjunction with the development of a primary industry provide both an opportunity and a challenge. Our research suggests that the options are limited but there may be an opportunity to develop an industry in conjunction with the private resource. Woodchip export is the most likely option and, in our opinion, should not be rejected simply on the grounds of low value-adding. A strong, viable residue utilising industry will be essential to the ongoing viability of a value-adding industry.

One alternative to export woodchip is the use of residues as biofuels. This has previously been explored in Hawaii and is currently being seriously considered in a number of countries. The use of residues as biofuels may be more politically and socially acceptable than the export of a low value product such as woodchips.